

APPENDIX H

**STATISTICAL AND GEOCHEMICAL EVALUATIONS
OF SITE METALS DATA**

STATISTICAL

Statistical Comparison of Site and Background Data For the Stump Dump, Parcel 82(7) Fort McClellan, Alabama

1.0 Introduction

This report provides the Tier 1 and Tier 2 (Shaw E&I, 2003) site-to-background comparison results for the Stump Dump, Parcel 82(7), Fort McClellan, in Calhoun County, Alabama. In the first step of the comparison, the maximum detected concentration (MDC) of each element is compared to two times the arithmetic mean of the background data (SAIC, 1998). Any metal that has an MDC greater than the background screening value is carried forward for Tier 2 evaluation, which includes the Slippage Test and the Wilcoxon Rank Sum Test (WRS). If either or both of these statistical test cannot be done, the evaluation will include the Hot Measurement Test.

The methodology and results of the Tier 1 and Tier 2 comparisons are summarized in Tables 1 through 5, and described in more detail in the following sections. Site samples used in the site-to-background comparison include 14 surface soil samples (0 to 2 feet below ground surface [bgs]), 4 subsurface soil (7 to 13 feet bgs), 8 groundwater samples, 5 sediment samples, and 5 surface water samples that were collected at the site.

Background distributions and screening values have been established for target analyte list (TAL) metals in surface soil, subsurface soil, groundwater, sediment, and surface water for Fort McClellan (SAIC, 1998).

2.0 Comparison Methodology

This section describes the statistical techniques that were employed in the Stump Dump, Parcel 82(7), site-to-background comparison.

2.1 Statistical Procedures

Contamination can be caused by a variety of processes that yield different spatial distributions of elevated contaminant concentrations. Slight but pervasive contamination can occur from non-point-source releases, and can result in slight increases in contaminant concentrations in a large percentage of samples. Localized, or “hot-spot,” contamination can result in elevated concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason,

Table 1

**Summary of Tier 1 and Tier 2 Site to Background Comparison for
Surface Soil
Stump Dump, Parcel 82(7)
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation ^a	Slippage Test ^b	Wilcoxon Rank Sum Test ^b	Hot Measurement Test ^{b,c}	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	14 / 14	Failed	Passed	Passed	NA	
Antimony	0 / 14	NA	NA	NA	NA	
Arsenic	14 / 14	Passed	NA	NA	NA	
Barium	14 / 14	Failed	Passed	Failed	NA	Yes
Beryllium	9 / 14	Failed	Failed	Failed	NA	Yes
Cadmium	0 / 14	NA	NA	NA	NA	
Calcium	4 / 14	Failed	Passed	NA ^d	Failed	Yes
Chromium	14 / 14	Passed	NA	NA	NA	
Cobalt	13 / 14	Failed	Passed	Failed	NA	Yes
Copper	14 / 14	Failed	Passed	Failed	NA	Yes
Iron	14 / 14	Failed	Passed	Failed	NA	Yes
Lead	14 / 14	Failed	Passed	Passed	NA	
Magnesium	7 / 14	Failed	Passed	NA ^d	Passed	
Manganese	14 / 14	Failed	Passed	Passed	NA	
Mercury	6 / 14	Failed	Passed	NA ^d	Failed	Yes
Nickel	13 / 14	Failed	Passed	Failed	NA	Yes
Potassium	9 / 14	Failed	Passed	Failed	NA	Yes
Selenium	5 / 14	Failed	Passed	NA ^d	Failed	Yes
Silver	2 / 14	Failed	Passed	NA ^d	Failed	Yes
Sodium	0 / 14	NA	NA	NA	NA	
Thallium	2 / 14	Passed	NA	NA	NA	
Vanadium	11 / 14	Passed	NA	NA	NA	
Zinc	14 / 14	Failed	Passed	Failed	NA	Yes

NA = not applicable; MDC = maximum detected concentration

a Tier 1 evaluation (site MDC compared to 2 x the background mean) per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d WRS test is not performed on data sets containing 50% or more nondetects.

Table 2

**Summary of Tier 1 and Tier 2 Site to Background Comparison
for Subsurface Soil
Stump Dump, Parcel 82(7)
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation ^a	Slippage Test ^b	Wilcoxon Rank Sum Test ^b	Hot Measurement Test ^{b,c}	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	4 / 4	Failed	Passed	NA ^e	Passed	
Antimony	0 / 4	NA	NA	NA	NA	
Arsenic	4 / 4	Passed	NA	NA	NA	
Barium	4 / 4	Passed	NA	NA	NA	
Beryllium	3 / 4	Failed	Passed	NA ^e	Passed	
Cadmium	1 / 4	Failed	Passed	NA ^e	Passed	
Calcium	1 / 4	Failed	Passed	NA ^e	Failed	Yes
Chromium	4 / 4	Failed	Passed	NA ^e	Passed	
Cobalt	4 / 4	Passed	NA	NA	NA	
Copper	4 / 4	Failed	Passed	NA ^e	Passed	
Iron	4 / 4	Passed	NA	NA	NA	
Lead	4 / 4	Passed	NA	NA	NA	
Magnesium	4 / 4	Failed	Passed	NA ^e	Failed	Yes
Manganese	4 / 4	Passed	NA	NA	NA	
Mercury	1 / 4	Passed	NA	NA	NA	
Nickel	4 / 4	Failed	Passed	NA ^e	Passed	
Potassium	4 / 4	Failed	Passed	NA ^e	Failed	Yes
Selenium	1 / 4	Failed	NA ^d	NA ^e	Failed	Yes
Silver	2 / 4	Failed	NA ^d	NA ^e	Failed	Yes
Sodium	0 / 4	NA	NA	NA	NA	
Thallium	1 / 4	Passed	NA	NA	NA	
Vanadium	3 / 4	Passed	NA	NA	NA	
Zinc	4 / 4	Failed	Passed	NA ^e	Passed	

NA = not applicable; MDC = maximum detected concentration

a Tier 1 evaluation (site MDC compared to 2 x the background mean) per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets with sample sizes less than 5.

Table 3

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Groundwater
Stump Dump, Parcel 82(7)
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation ^a	Slippage Test ^b	Wilcoxon Rank Sum Test ^b	Hot Measurement Test ^{b,c}	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	8 / 8	Failed	Passed	Passed	NA	
Antimony	0 / 8	NA	NA	NA	NA	
Arsenic	0 / 8	NA	NA	NA	NA	
Barium	8 / 8	Failed	Passed	Passed	NA	
Beryllium	0 / 8	NA	NA	NA	NA	
Cadmium	0 / 8	NA	NA	NA	NA	
Calcium	8 / 8	Passed	NA	NA	NA	
Chromium	4 / 8	Failed	NA ^d	NA ^e	Passed	
Cobalt	2 / 8	Passed	NA	NA	NA	
Copper	4 / 8	Passed	NA	NA	NA	
Iron	7 / 8	Failed	Passed	Passed	NA	
Lead	1 / 8	Failed	NA ^d	NA ^e	Passed	
Magnesium	8 / 8	Passed	NA	NA	NA	
Manganese	8 / 8	Failed	Passed	Passed	NA	
Mercury	0 / 8	NA	NA	NA	NA	
Nickel	4 / 8	Failed	NA ^d	NA ^e	Passed	
Potassium	0 / 8	NA	NA	NA	NA	
Selenium	0 / 8	NA	NA	NA	NA	
Silver	0 / 8	NA	NA	NA	NA	
Sodium	8 / 8	Passed	NA	NA	NA	
Thallium	0 / 8	NA	NA	NA	NA	
Vanadium	0 / 8	NA	NA	NA	NA	
Zinc	0 / 8	NA	NA	NA	NA	

NA = not applicable; MDC = maximum detected concentration

a Tier 1 evaluation (site MDC compared to 2 x the background mean) per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets containing 50% or more nondetects.

Table 4

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Sediment
Stump Dump, Parcel 82(7)
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation ^a	Slippage Test ^b	Wilcoxon Rank Sum Test ^b	Hot Measurement Test ^{b,c}	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	5 / 5	Failed	Passed	Passed	NA	
Antimony	0 / 5	NA	NA	NA	NA	
Arsenic	5 / 5	Passed	NA	NA	NA	
Barium	5 / 5	Failed	Passed	Failed	NA	Yes
Beryllium	5 / 5	Failed	Passed	Passed	NA	
Cadmium	0 / 5	NA	NA	NA	NA	
Calcium	5 / 5	Failed	Passed	Passed	NA	
Chromium	5 / 5	Passed	NA	NA	NA	
Cobalt	5 / 5	Passed	NA	NA	NA	
Copper	5 / 5	Failed	Passed	Passed	NA	
Iron	5 / 5	Passed	NA	NA	NA	
Lead	5 / 5	Passed	NA	NA	NA	
Magnesium	5 / 5	Failed	Passed	Passed	NA	
Manganese	5 / 5	Passed	NA	NA	NA	
Mercury	5 / 5	Passed	NA	NA	NA	
Nickel	5 / 5	Failed	Passed	Passed	NA	
Potassium	5 / 5	Failed	Passed	Failed	NA	Yes
Selenium	3 / 5	Failed	Passed	NA ^d	Failed	Yes
Silver	0 / 5	NA	NA	NA	NA	
Sodium	0 / 5	NA	NA	NA	NA	
Thallium	0 / 5	NA	NA	NA	NA	
Vanadium	5 / 5	Passed	NA	NA	NA	
Zinc	5 / 5	Passed	NA	NA	NA	

NA = not applicable; MDC = maximum detected concentration

a Tier 1 evaluation (site MDC compared to 2 x the background mean) per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d WRS test is not performed on data sets containing 50% or more nondetects.

Table 5

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Water
Stump Dump, Parcel 82(7)
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation ^a	Slippage Test ^b	Wilcoxon Rank Sum Test ^b	Hot Measurement Test ^{b,c}	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	5 / 5	Failed	Passed	Failed	NA	Yes
Antimony	0 / 5	NA	NA	NA	NA	
Arsenic	1 / 5	Failed	Passed	NA ^d	Failed	Yes
Barium	5 / 5	Passed	NA	NA	NA	
Beryllium	0 / 5	NA	NA	NA	NA	Yes
Cadmium	0 / 5	NA	NA	NA	NA	
Calcium	5 / 5	Passed	NA	NA	NA	
Chromium	3 / 5	Passed	NA	NA	NA	
Cobalt	0 / 5	NA	NA	NA	NA	
Copper	0 / 5	NA	NA	NA	NA	
Iron	5 / 5	Passed	NA	NA	NA	
Lead	1 / 5	Passed	NA	NA	NA	
Magnesium	5 / 5	Passed	NA	NA	NA	
Manganese	5 / 5	Passed	NA	NA	NA	
Mercury	0 / 5	NA	NA	NA	NA	
Nickel	0 / 5	NA	NA	NA	NA	
Potassium	5 / 5	Failed	Passed	Failed	NA	
Selenium	0 / 5	NA	NA	NA	NA	
Silver	0 / 5	NA	NA	NA	NA	
Sodium	0 / 5	NA	NA	NA	NA	
Thallium	0 / 5	NA	NA	NA	NA	
Vanadium	3 / 5	Passed	NA	NA	NA	
Zinc	2 / 5	Passed	NA	NA	NA	

NA = not applicable; MDC = maximum detected concentration

a Tier 1 evaluation (site MDC compared to 2 x the background mean) per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d WRS test is not performed on data sets containing 50% or more nondetects.

the use of several simultaneous tests is recommended for a valid and complete comparison of site versus background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 2002).

Analytes that fail the Tier 1 and Tier 2 comparisons are subject to a geochemical evaluation to determine if the elevated concentrations are due to natural processes or if they represent potential contamination.

2.1.1 Tier 1

In this step of the background screening process, MDC of the site data set is compared to the background screening value of two times the background mean (SAIC, 1998). Elements for which the site MDC does not exceed the background screening value are considered to be present at background concentrations, and are not considered site-related chemicals. Elements for which the site MDC exceeds the background screening value undergo further evaluation (Tier 2).

2.1.2 Tier 2

Slippage Test. The nonparametric Slippage test is designed to detect a difference between the upper tails of two distributions, and has been recommended for use in site-to-background comparisons to identify potential localized, or hot-spot, contamination (U.S. Navy, 2002). The test is performed by counting the number (K) of detected concentrations in the site data set that exceed the maximum background measurement, and then comparing this number to a critical value (K_c), which is a function of the number of background samples and the number of site samples. If $K > K_c$, then potential contamination is indicated and the analyte will be subjected to geochemical evaluation. If $K \leq K_c$, then localized contamination is not suspected.

Critical values tables for site and background data sets up to size $n = 50$ are provided in U.S. Navy (2002). Critical values for larger data sets are calculated using the test statistic provided in Rosenbaum (1954). In this report, the Slippage test is performed at the 95 percent confidence level. The test cannot be performed if the maximum background value is a nondetect, because the actual concentration in that sample is unknown.

Wilcoxon Rank Sum Test. The nonparametric WRS test is designed to detect a difference between the medians of two data sets, and has been recommended for use in site-to-background comparisons to identify slight but pervasive contamination (EPA, 2000; U.S. Navy, 2002). In this report, the WRS test is performed when the site and background data sets each contain less

than 50 percent nondetects (i.e., measurements reported as not detected below the laboratory reporting limit). The WRS test will not be performed on data sets containing 50 percent or more nondetects. The medians of such data sets are unknown, and hence the test results would lack sufficient power to yield reliable results.

The WRS test compares two data sets of size n and m ($n > m$), and tests the null hypothesis that the samples were drawn from populations with distributions having the same medians. To perform the test, the two sets of observations are pooled and arranged in order from smallest to largest. Each observation is assigned a rank; that is, the smallest is ranked 1, the next largest is ranked 2, and so on up to the largest observation, which is ranked $(n + m)$. If ties occur between or within samples, each one is assigned the mid-rank. Next, the sum of the ranks of smaller data set m is calculated. Then the test statistic Z is determined,

$$Z = \frac{W - m(m + n + 1)/2}{\sqrt{mn(m + n + 1)/12}}$$

Where:

W = Sum of the ranks of the smaller data set

m = Number of data points in smaller group

n = Number of data points in larger group.

This test statistic Z is used to find the two-sided significance. For instance, if the test statistic yields a probability of a Type I error (p-level) less than 0.2, then there is a statistically significant difference between the medians at the 80 percent confidence level. A Type I error involves rejecting the null hypothesis when it is true. If the p-level is greater than 0.2, then there is no reasonable justification to reject the null hypothesis at the 80 percent confidence level. It can therefore be concluded that the medians of the two data sets are similar, and it can be assumed to be drawn from the same population.

If the p-level is less than 0.2, then the medians of the two distributions are significantly different at the 80 percent confidence level. This can occur if the site data are shifted higher or lower than the background data. If the site data are shifted higher relative to background, then contamination may be indicated, and the analyte in question will be carried on for geochemical evaluation; however, if the site data are shifted lower relative to background, then contamination is not indicated. If the p-level is greater than 0.2, then pervasive site contamination is not suspected.

Box Plots. A quick, robust graphical method recommended by the EPA to visualize and compare two or more groups of data is the box plot comparison (EPA, 1989 and 1992). These plots provide a summary view of the entire data set, including the overall location and degree of symmetry. The box encloses the central 50 percent of the data points so that the top of the box represents the 75th percentile and the bottom of the box represents the 25th percentile. The small box within the larger box represents the median of the data set. The upper whisker extends outward from the box to the maximum point and the lower whisker extends to the minimum point. Nondetect results are set equal to one-half of the reporting limit for plotting purposes.

For each analyte, box plots of site and background data are placed side by side to visually compare the distributions and qualitatively determine whether the data sets are similar or distinct. Accordingly, the box plots are a necessary adjunct to the WRS test. As described previously, the WRS test may indicate that the medians of the site and background data sets are significantly different. Examination of the box plots will confirm whether that difference is caused by site data that are shifted higher or lower relative to background.

Hot Measurement Test. The hot measurement test consists of comparing each site measurement with a concentration value that is representative of the upper limit of the background distribution (EPA, 1994). Ideally, a site sample with a concentration above the background screening value would have a low probability of being a member of the background distribution, and may be an indicator of contamination. It is important to select such a background screening value carefully so that the probability of falsely identifying site samples as contaminated or uncontaminated is minimized.

The 95th upper tolerance limit (95th UTL) is recommended as a screening value for normally or lognormally distributed analytes and the 95th percentile is recommended as a screening value for nonparametrically distributed analytes (EPA, 1989, 1992, and 1994). Site samples with concentrations above these values are not necessarily contaminated, but should be considered suspect. To perform the test, each analyte's site MDC is compared to the background 95th UTL or 95th percentile, in accordance with the type of background distribution. If the site MDC exceeds the background screening value, then that analyte will undergo a geochemical evaluation. If the MDC does not exceed the background threshold value, then hot-spot contamination is not indicated.

2.1.3 Geochemical Evaluation

If an analyte fails either of the statistical tests described above, then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The methodology and results of the geochemical evaluation are provided separately in this appendix.

3.0 Results of the Site-to-Background Comparisons

This section presents the results of the site-to-background comparisons for 23 TAL metals in the Stump Dump, Parcel 82(7), soil, groundwater, sediment, and surface water samples. Tables 1 through 5 summarize the Tier 1 and Tier 2 test results for each media as discussed in the following sections. Statistical test results are discussed in detail below. Box plots are also discussed below and are provided in Attachment 1.

3.1 Surface Soil

Twenty-three TAL metals were evaluated in the Stump Dump surface soil. Three metals, antimony, cadmium, and sodium, had no detected concentrations in surface soil, so no further discussion of these metals is included. Arsenic, chromium, thallium, and vanadium had no detected concentrations above the background screening value, passing the Tier 1 evaluation. They will not be tested or discussed any further.

The remaining 16 metals underwent Tier 2 evaluation. The statistical test results and box plots are discussed in detail below.

Table 1 summarizes the Tier 1 and Tier 2 test results for surface soil.

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 16,306 milligrams per kilogram (mg/kg).

Slippage Test

The critical value, K_c , for aluminum is 2. Aluminum has no site samples exceeding the maximum background measurement ($K=0$). Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The WRS test p-level of 0.056 indicates a significant difference between the site and background distributions. The box plot demonstrates visually that this difference is because site data is actually lower than background.

Box Plot

Box plots for the site and background data sets are provided in Figure 1-1. The site minimum, 25th percentile, median, and maximum are lower than the corresponding background values. The site and background 75th percentiles are similar.

Conclusion

Aluminum in surface soil is considered to be within the range of background.

Barium

Tier 1 Evaluation

Three site samples exceed the background screening value of 123.94 mg/kg.

Slippage Test

K_c for barium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, barium passes the Slippage test.

WRS Test

The p-level of 0.012 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-1). The site minimum is slightly less than background.

Conclusion

Because barium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Beryllium

Tier 1 Evaluation

Five site samples exceed the background screening value of 0.8 mg/kg.

Slippage Test

The critical value, K_c is 2, and 5 site samples exceed the maximum background measurement. Because $K > K_c$, beryllium fails the Slippage test.

WRS Test

The p-level 0.0124 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-2).

Conclusion

Because beryllium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Calcium

Tier 1 Evaluation

One site sample exceeds the background screening value of 1,723 mg/kg.

Slippage Test

K_c for calcium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, calcium passes the Slippage test.

WRS Test

The WRS test was not performed because the site data consisted of more than 50 percent nondetects.

Box Plot

The site minimum and 25th percentile are higher than that of background (Figure 1-2). The site median is just slightly elevated compared to that of background. The site 75th percentile and maximum are less than the corresponding background values. The shape and location of the site box plot is influenced by the high percentage of nondetects (71 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The maximum detected result exceeds the background 95th UTL of 3,545 mg/kg.

Conclusion

Because calcium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cobalt

Tier 1 Evaluation

Four site samples exceed the background screening value of 15.15 mg/kg.

Slippage Test

K_c for cobalt is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, cobalt passes the Slippage test.

WRS Test

The p-level of 0.0047 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-3). The site minimum is less than that of background.

Conclusion

Because cobalt in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Copper

Tier 1 Evaluation

Seven site samples exceed the background screening value of 12.71 mg/kg.

Slippage Test

K_c for copper is 2, and 2 site samples exceed the maximum background measurement. Because $K \leq K_c$, copper passes the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-3).

Conclusion

Because copper in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Iron

Tier 1 Evaluation

Two site samples exceed the background screening value of 34,154 mg/kg.

Slippage Test

K_c for iron is 2, and no site sample exceeds the maximum background measurement. Because $K < K_c$, iron passes the Slippage test.

WRS Test

The p-level of 0.00698 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-4). The site maximum is less than that of background.

Conclusion

Because iron in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Lead

Tier 1 Evaluation

One site sample exceeds the background screening value of 40.05 mg/kg.

Slippage Test

K_c for lead is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, lead passes the Slippage test.

WRS Test

The p-level of 0.2186 indicates good agreement between the site and background distributions.

Box Plot

The site minimum is slightly higher than that of background. The site interquartile range is slightly lower than the corresponding background values (Figure 1-4). The site maximum is lower than that of background.

Conclusion

Lead in surface soil is considered to be within the range of background.

Magnesium

Tier 1 Evaluation

Two site samples exceed the background screening value of 1,033 mg/kg.

Slippage Test

K_c for magnesium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

WRS Test

The WRS test was not performed because the site data consisted of 50 percent nondetects.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-5). The site maximum is lower compared to that of background. The shape and location of the site box plot is influenced by the percentage of nondetects (50 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The maximum detected result is less than the background 95th percentile of 2,160 mg/kg.

Conclusion

Magnesium in surface soil is considered to be within the range of background.

Manganese

Tier 1 Evaluation

One site sample exceeds the background screening value of 1,579 mg/kg.

Slippage Test

The critical value, K_c , for manganese is 2. No detects in site samples exceed the maximum background measurement. Because $K < K_c$, manganese passes the Slippage test.

WRS Test

The p-level of 0.336 indicates excellent agreement between the site and background distributions.

Box Plot

The site minimum, 25th percentile, and median are higher than their respective background values (Figure 1-5). The site 75th percentile is just slightly lower than that of background. The site maximum is less than the corresponding background value.

Conclusion

Manganese in surface soil is considered to be within the range of background.

Mercury

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.08 mg/kg.

Slippage Test

K_c for mercury is 2, and no site sample exceeds the maximum background measurement. Because $K < K_c$, mercury passes the Slippage test.

WRS Test

The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot

The site 25th percentile, median, and maximum are less than the corresponding background values (Figure 1-6). The site minimum and 75th percentile are higher than that of background. The shape and location of the background and site box plots are influenced by the percentage of nondetects (66 percent and 57 percent, respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 0.125 mg/kg.

Conclusion

Because mercury in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Nickel

Tier 1 Evaluation

Four site samples exceed the background screening value of 10.33 mg/kg.

Slippage Test

K_c for nickel is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$ nickel passes the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding range of background values (Figure 1-6).

Conclusion

Because nickel in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Potassium

Tier 1 Evaluation

Three site samples exceed the background screening value of 799.76 mg/kg.

Slippage Test

K_c for potassium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, potassium passes the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-7). The site maximum is less than that of background.

Conclusion

Because potassium in surface soil failed statistical comparison to background, it is carried forward for Tier 3 geochemical evaluation.

Selenium

Tier 1 Evaluation

Five site samples exceed the background screening value of 0.48 mg/kg.

Slippage Test

K_c for selenium is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, selenium passes the Slippage test.

WRS Test

No WRS test was performed because the site and background data sets contain more than 50 percent nondetects.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-7). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (99 percent and 64 percent, respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 0.563 mg/kg.

Conclusion

Because selenium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Silver

Tier 1 Evaluation

Two site samples exceed the background screening value of 0.36 mg/kg.

Slippage Test

K_c for silver is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, silver passes the Slippage test.

WRS Test

No WRS test was performed because the site data set contains more than 50 percent nondetects.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-8). The site maximum is slightly lower than that of background. The shape and location of the site box plot is influenced by the high percentage of nondetects (86 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 0.774 mg/kg.

Conclusion

Because silver in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Zinc

Tier 1 Evaluation

Two site samples exceed the background screening value of 40.64 mg/kg.

Slippage Test

K_c for zinc is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, zinc passes the Slippage test.

WRS Test

The p-level of 0.06 indicates weak agreement between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher compared to the respective background values (Figure 1-8). The site maximum is lower compared to the corresponding background value.

Conclusion

Because zinc in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

3.2 Subsurface Soil

Twenty-three TAL metals were evaluated in the Stump Dump (Parcel 82(7)), subsurface soil. Two metals, antimony and sodium, had no detected concentrations. No further discussion of these metals is included.

Nine metals, arsenic, barium, cobalt, iron, lead, manganese, mercury, thallium, and vanadium, had no detected concentrations above the background screening value, passing the Tier 1 evaluation. No further testing or discussion of these three metals is included.

The remaining 12 metals underwent Tier 2 evaluation. The statistical tests and box plots are discussed in detail below.

Table 2 summarizes the Tier 1 and Tier 2 test results for subsurface soil.

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 13,591 mg/kg.

Slippage Test

The critical value, K_c , for aluminum is 2. No site samples exceed the maximum background measurement. Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

Box plots for the site and background data sets are provided in Figure 1-9. The site and background medians are similar. The site 25th percentile and maximum are lower than the corresponding background values. The site 75th percentile is higher than that of background.

Hot Measurement Test

The site MDC is less than the background 95th UTL of 16,574 mg/kg.

Conclusion

Aluminum in subsurface soil is considered to be within the range of background.

Beryllium

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.86 mg/kg.

Slippage Test

K_c for beryllium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, beryllium passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-9). The site maximum is lower than that of background.

Hot Measurement Test

The site MDC for beryllium is less than the background 95th UTL of 2.19 mg/kg.

Conclusion

Based on statistical comparison to background, beryllium in subsurface soil is considered to be within the range of background.

Cadmium

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.22 mg/kg.

Slippage Test

K_c for cadmium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, cadmium passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-10). The site maximum is less than that of background.

Hot Measurement Test

The site MDC is less than the background 95th UTL of 0.62 mg/kg.

Conclusion

Cadmium in subsurface soil is considered to be within the range of background.

Calcium

Tier 1 Evaluation

One site sample exceeds the background screening value of 637.17 mg/kg.

Slippage Test

K_c for calcium is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, calcium passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-10).

Hot Measurement Test

The site MDC for calcium exceeds the background 95th UTL of 1,710 mg/kg.

Conclusion

Because calcium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Chromium

Tier 1 Evaluation

One site sample exceeds the background screening value of 38.25 mg/kg.

Slippage Test

K_c for chromium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, chromium passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site interquartile range is slightly higher than the corresponding background range (Figure 1-11). The site minimum is much higher than that of background, and the site maximum is lower than that of background.

Hot Measurement Test

The site MDC is less than the background 95th UTL of 53.4 mg/kg.

Conclusion

Chromium in subsurface soil is considered to be within the range of background.

Copper

Tier 1 Evaluation

Two site samples exceed the background screening value of 19.43 mg/kg.

Slippage Test

K_c for copper is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, copper passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-11). The site maximum is lower than that of background.

Hot Measurement Test

The site MDC for copper is less than the 95th UTL of 34.2 mg/kg.

Conclusion

Copper in subsurface soil is considered to be within the range of background.

Magnesium

Tier 1 Evaluation

Two site samples exceed the background screening value of 766.24 mg/kg.

Slippage Test

K_c for magnesium is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-12).

Hot Measurement Test

The site MDC of magnesium is greater than the background 95th percentile of 2,270 mg/kg.

Conclusion

Because magnesium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Nickel

Tier 1 Evaluation

Three site samples exceed the background screening value of 12.89 mg/kg.

Slippage Test

K_c for nickel is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, nickel passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are higher than that of the corresponding background values (Figure 1-12). The site maximum is less than that of background.

Hot Measurement Test

The site MDC is less than the background 95th percentile of 29.2 mg/kg.

Conclusion

Nickel in subsurface soil is considered to be within the range of background.

Potassium

Tier 1 Evaluation

Three site samples exceed the background screening value of 710.74 mg/kg.

Slippage Test

K_c for potassium is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, potassium passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-13). The site maximum is similar to that of background.

Hot Measurement Test

The site MDC of potassium exceeds the background 95th UTL of 1,420 mg/kg.

Conclusion

Because potassium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Selenium

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.47 mg/kg.

Slippage Test

The maximum result in background is a nondetect, so the Slippage test is not done.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-13).

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 0.574 mg/kg.

Conclusion

Because selenium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Silver

Tier 1 Evaluation

Two site samples exceed the background screening value of 0.24 mg/kg.

Slippage Test

The maximum result in background is a nondetect, so the Slippage test is not done.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are significantly higher than the corresponding background values (Figure 1-14). The site maximum is slightly higher than that of background.

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 0.88 mg/kg.

Conclusion

Because silver in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Zinc

Tier 1 Evaluation

One site sample exceeds the background screening value of 34.86 mg/kg.

Slippage Test

K_c for zinc is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, zinc passes the Slippage test.

WRS Test

The WRS test was not performed because the data set has less than 5 samples.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-14). The site maximum is less than that of background.

Conclusion

Zinc in subsurface soil is considered to be within the range of background.

3.3 Groundwater

This section presents the results of the site-to-background comparisons for 23 metals in unfiltered groundwater samples.

Eleven metals (antimony, arsenic, beryllium, cadmium, mercury, potassium, selenium, silver, thallium, vanadium, and zinc) had no detected results in the site samples and are not discussed any further.

Five metals had no detected concentrations that exceeded the background screening value, passing the Tier 1 evaluation. These metals (calcium, cobalt, copper, magnesium, and sodium) will not be included in any further evaluation or discussion.

The remaining seven metals underwent Tier 2 evaluation. The results of these statistical tests are discussed in detail below and summarized in Table 3. Box plots are provided in Attachment 1.

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 2.335 mg/L.

Slippage Test

The critical value, K_c , for aluminum is 2. No site samples exceed the maximum background measurement ($K = 0$). Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The p-level of 0.58 indicates strong agreement between the site and background distributions.

Box Plot

The site 75th percentile and maximum are lower than the corresponding background values (Figure 1-15). The site minimum, 25th percentile, and median are slightly higher than that of background.

Conclusion

Aluminum in groundwater is considered to be within the range of background.

Barium

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.127 mg/L.

Slippage Test

The critical value, K_c , for barium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, barium passes the Slippage test.

WRS Test

The p-level of 0.85 indicates excellent agreement between the site and background distributions.

Box Plot

The site 25th percentile and median are slightly lower than the corresponding background values (Figure 1-15). The site minimum and 75th percentile are slightly higher than that of background, and the site maximum is lower than that of background.

Conclusion

Barium in groundwater is considered to be within the range of background.

Chromium

Tier 1 Evaluation

There is no background screening value for chromium. Four site samples have detected concentrations.

Slippage Test

The maximum value for chromium is a nondetect, so the Slippage test was not performed.

WRS Test

The WRS test was not performed because the site and background data sets contain 50 percent or more nondetects.

Box Plot

The site 25th percentile and median appear similar to the corresponding background values (Figure 1-16). The site 75th percentile is lower than that of background, and the site minimum and maximum are higher than the corresponding background values. The shape and location of

the background and site box plots are influenced by the percentage of nondetects (100 percent and 50 percent, respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC is less than the background 95th percentile of 0.0168 mg/L.

Conclusion

Chromium in groundwater is considered to be within the range of background.

Iron

Tier 1 Evaluation

One site sample exceeds the background screening value of 7.04 mg/L.

Slippage Test

K_c for iron is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, iron passes the Slippage test.

WRS Test

The p-level of 0.817 indicates excellent agreement between the site and background distributions.

Box Plot

The site median, 75th percentile, and maximum are lower than the corresponding background values (Figure 1-16). The site minimum and 25th percentile are higher than that of background.

Conclusion

Iron in groundwater is considered to be within the range of background.

Lead

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.007998 mg/L.

Slippage Test

The maximum value for lead is a nondetect, so the Slippage test was not performed.

WRS Test

The WRS test was not performed because the site and background data sets contain 50 percent or more nondetects.

Box Plot

The site median, 75th percentile, and maximum are lower than the corresponding background values (Figure 1-17). The site minimum and 25th percentile are higher than that of background. The shape and location of the background and site box plots are influenced by the high percentage of nondetects (60 percent and 87 percent, respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC of lead is less than the background 95th percentile of 0.0434 mg/L.

Conclusion

Lead in groundwater is considered to be within the range of background.

Manganese

Tier 1 Evaluation

Two site samples exceed the background screening value of 0.5805 mg/L.

Slippage Test

K_c for manganese is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, manganese passes the Slippage test.

WRS Test

The p-level of 0.366 indicates good agreement between the site and background distributions.

Box Plot

The site median is similar to that of background, and the site maximum is lower than the background maximum (Figure 1-17). The site minimum, 25th percentile, and 75th percentile are higher than the corresponding background values.

Conclusion

Manganese in groundwater is considered to be within the range of background.

Nickel

Tier 1 Evaluation

No background screening value is available for nickel. Four site samples have detected concentrations.

Slippage Test

The Slippage test was not performed because the maximum value in the background data is a nondetect.

WRS Test

The WRS test was not performed because the site and background data sets have 50 percent of more nondetects.

Box Plot

The site minimum, interquartile range and maximum are higher than the corresponding background values (Figure 1-18). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (100 percent and 50 percent, respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC is less than the background 95th percentile of 0.0343 mg/L.

Conclusion

Nickel in groundwater is considered to be within the range of background.

3.4 Sediment

This section presents the results of the site-to-background comparisons for 23 TAL metals for the Stump Dump, Parcel 82(7) sediment samples. Five metals (antimony, cadmium, silver, sodium, and thallium) had no detected concentrations in sediment. No further discussion of these elements is included.

Nine metals (arsenic, chromium, cobalt, iron, lead, manganese, mercury, vanadium, and zinc) had no site samples exceeding their respective background screening value. Because these metals passed the Tier 1 evaluation, they will not be tested or discussed any further.

The remaining nine metals underwent Tier 2 evaluation and are discussed in detail below. Box plots are provided in Attachment 1.

Table 4 summarizes the Tier 1 and Tier 2 results for sediment.

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 8,593 mg/kg.

Slippage Test

The critical value, K_c , for aluminum is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The WRS test p-level of 0.245 indicates good agreement between the site and background distributions.

Box Plot

Box plots for the site and background data sets are provided in Figure 1-18. The site minimum, 25th percentile, and median are higher than the corresponding background values. The site 75th percentile is similar to that of background, and the site minimum is less than that of background.

Conclusion

Aluminum in sediment is considered to be within the range of background.

Barium

Tier 1 Evaluation

Two site samples exceed the background screening value of 98.91 mg/kg.

Slippage Test

K_c for barium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, barium passes the Slippage test.

WRS Test

The p-level of 0.064 indicates weak agreement between the site and background distributions.

Box Plot

The site minimum is much higher than that of background, while the site interquartile range is slightly elevated compared to the corresponding background values (Figure 1-19). The site maximum is lower than that of background.

Conclusion

Because barium in sediment failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Beryllium

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.97 mg/kg.

Slippage Test

K_c for beryllium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, beryllium passes the Slippage test.

WRS Test

The p-level of 0.2268 indicates a good agreement between the site and background distributions.

Box Plot

The site minimum, 25th percentile and median are elevated compared to the corresponding background values (Figure 1-19). The site 75th percentile is similar to that of background, and the site maximum is slightly lower than the corresponding background value.

Conclusion

Beryllium in sediment is considered to be within the range of background.

Calcium

Tier 1 Evaluation

One site sample exceeds the background screening value of 1,111.51 mg/kg.

Slippage Test

K_c for calcium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, calcium passes the Slippage test.

WRS Test

The p-level of 0.91 indicates excellent agreement between the site and background distributions.

Box Plot

The site 25th percentile, 75th percentile, and maximum are slightly lower than the corresponding background values (Figure 1-20).

Conclusion

Calcium in sediment is considered to be within the range of background.

Copper

Tier 1 Evaluation

One site sample exceeds the background screening value of 17.12 mg/kg.

Slippage Test

K_c for copper is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, copper passes the Slippage test.

WRS Test

The p-level of 0.3847 indicates good agreement between the site and background distributions.

Box Plot

The site 75th percentile is similar to that of background, and the site maximum is lower than the corresponding background value (Figure 1-20). The site minimum, median, and 25th percentile are slightly higher than the corresponding background values.

Conclusion

Copper in sediment is considered within the range of background.

Magnesium

Tier 1 Evaluation

Two site samples exceed the background screening value of 905.94 mg/kg.

Slippage Test

K_c for magnesium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

WRS Test

The p-level of 0.43 indicates good agreement between the site and background distributions.

Box Plot

The site minimum, 25th percentile, median, and 75th percentile are higher than the corresponding background values (Figure 1-21). The site maximum is lower than that of background.

Conclusion

Magnesium in sediment is considered to be within the range of background.

Nickel

Tier 1 Evaluation

One site sample exceeds the background screening value of 13.02 mg/kg.

Slippage Test

K_c for nickel is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, nickel passes the Slippage test.

WRS Test

The p-level of 0.37 indicates good agreement between the site and background distributions.

Box Plot

The site minimum, 25th percentile, and median are higher than the corresponding background values (Figure 1-21). The site and background 75th percentiles are similar, and the site maximum is lower than that of background.

Conclusion

Nickel in sediment is considered to be within the range of background.

Potassium

Tier 1 Evaluation

One site sample exceeds the background screening value of 1,013.48 mg/kg.

Slippage Test

K_c for potassium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, potassium passes the Slippage test.

WRS Test

The p-level of 0.0268 indicates weak agreement between the site and background distributions.

Box Plot

The site minimum and interquartile range higher than the respective background values (Figure 1-22). The site maximum is lower than that of background.

Conclusion

Because potassium in sediment failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Selenium

Tier 1 Evaluation

Three site samples exceed the background screening value of 0.72 mg/kg.

Slippage Test

K_c for selenium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, selenium passes the Slippage test.

WRS Test

The WRS test was not performed because the background data set has more than 50 percent nondetects.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-22). The site maximum is lower than that of background. The shape and location of the background box plot is influenced by the high percentage of nondetects (93 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 1.03 mg/kg.

Conclusion

Because selenium in sediment failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

3.5 Surface Water

This section presents the results of the site-to-background comparisons for the 23 metals tested in surface water samples. Eleven metals (antimony, beryllium, cadmium, cobalt, copper, mercury, nickel, selenium, silver, sodium, and thallium) had no detected concentrations in the site samples and are not discussed any further.

Nine metals (barium, calcium, chromium, iron, lead, magnesium, manganese, vanadium, and zinc) had no detected concentrations exceeding their respective background screening values. These metals are considered within the range of background based on the Tier 1 evaluation, and will not be tested or discussed further.

The remaining three metals (aluminum, arsenic, and potassium) underwent Tier 2 evaluation. The results of these tests are discussed in detail below. Box plots are provided in Attachment 1.

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 5.259 mg/L.

Slippage Test

K_c for aluminum is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The p-level of 0.018 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-23). The site maximum is lower than that of background.

Conclusion

Because aluminum in surface water failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Arsenic

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.00217 mg/L.

Slippage Test

The critical value, K_c , for arsenic is 2. No site samples exceed the maximum background measurement. Because $K < K_c$, arsenic passes the Slippage test.

WRS Test

The WRS test was not performed because the background and site data sets have more than 50 percent nondetects.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-23). The site maximum is less than that of background. The shape and location of the background and site box plots are influenced by the high percentage of nondetects (86 percent and 80 percent, respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC for arsenic exceeds the background 95th percentile of 0.0034 mg/L.

Conclusion

Because arsenic in surface water failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Potassium

Tier 1 Evaluation

Four site samples exceed the background screening value of 2.564 mg/L.

Slippage Test

K_c for potassium is 2, and no site samples exceed the maximum background value. Because $K < K_c$, potassium passes the Slippage test.

WRS Test

The p -level < 0.001 indicates a significant difference between site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-24). The site maximum is lower than that of background.

Conclusion

Because potassium in surface water failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

4.0 Summary and Conclusions

The statistical methodology used to compare site data from the Stump Dump, Parcel 82(7), and the background data sets for 23 elements in surface soil, subsurface soil, groundwater, sediment, and surface water includes a comparison of the site MDC to the background screening value (Tier 1 evaluation). Analytes that failed this comparison were subjected to the Slippage test and Wilcoxon rank sum test, and box-and-whisker plots were prepared to visually compare the two data sets and properly interpret the WRS test results. If the Slippage test and/or the WRS test could not be performed, the Hot Measurement test was included as part of the Tier 2 statistical evaluation. Analytes that underwent Tier 2 evaluation and failed any component of the statistical site-to-background comparison are carried forward for Tier 3 geochemical evaluation to determine if natural processes can explain the elevated concentrations.

Tables 1 through 5 summarize the comparison test results and the metals carried forward for geochemical evaluation.

5.0 References

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ATTACHMENT 1

Figure 1-1

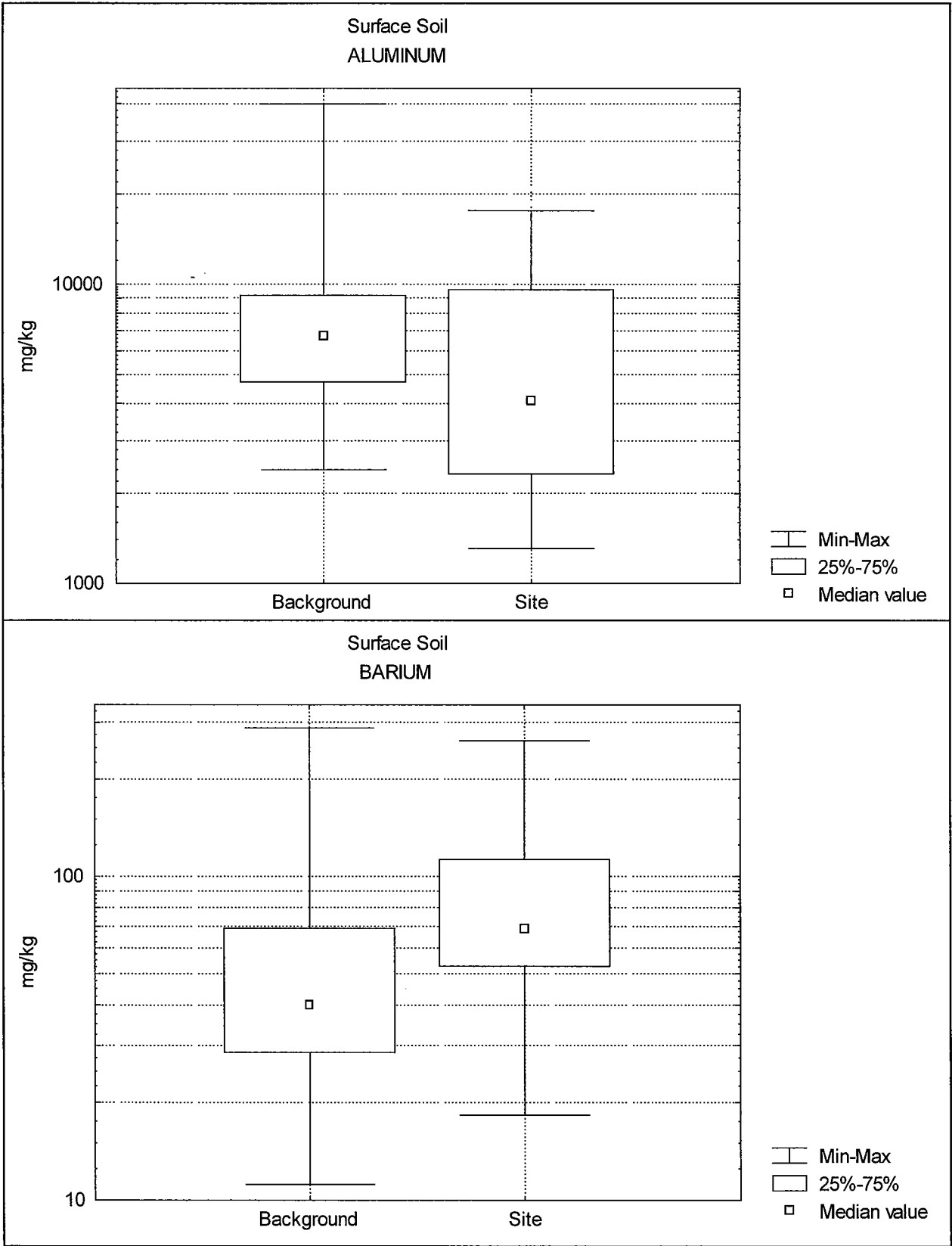


Figure 1-2

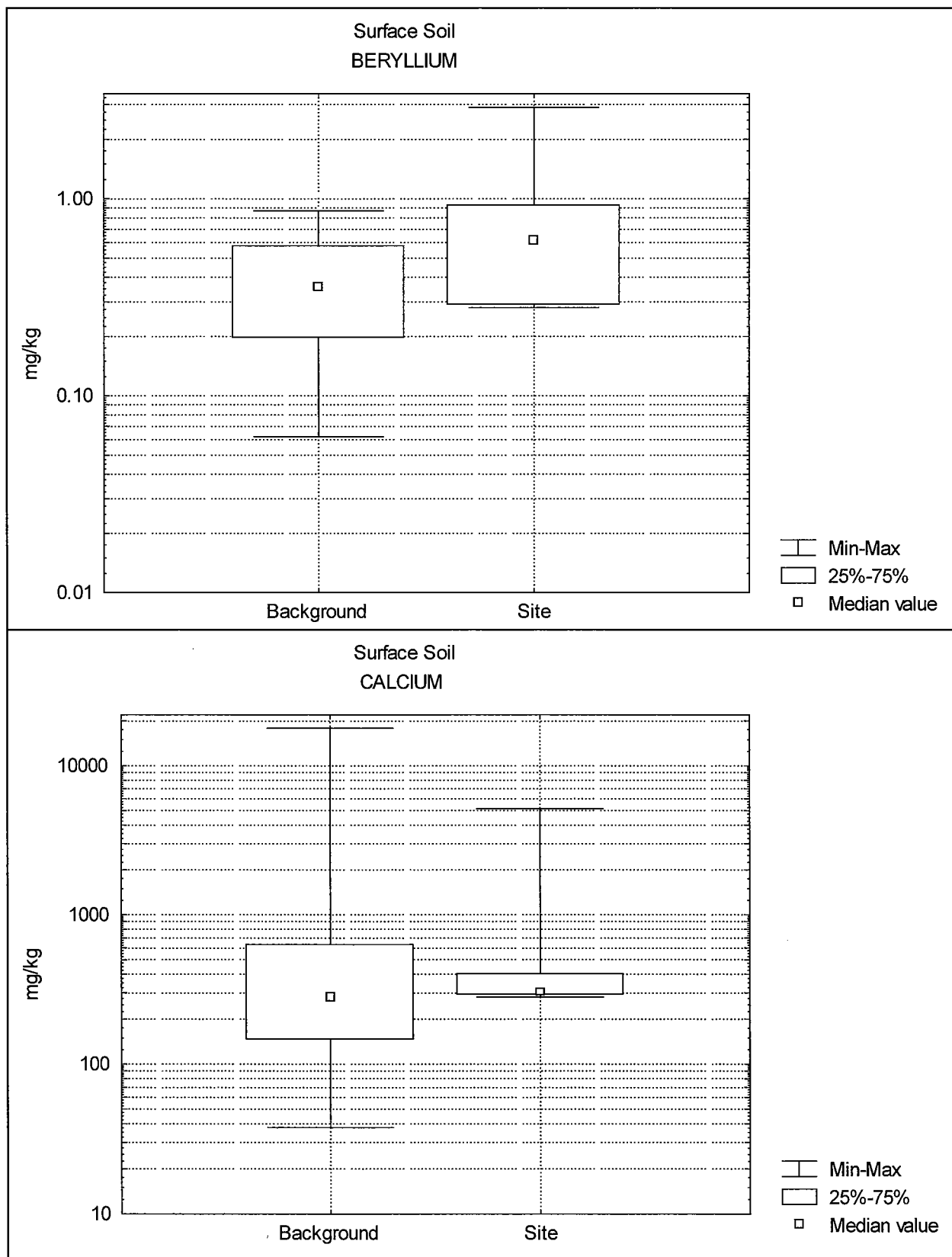


Figure 1-3

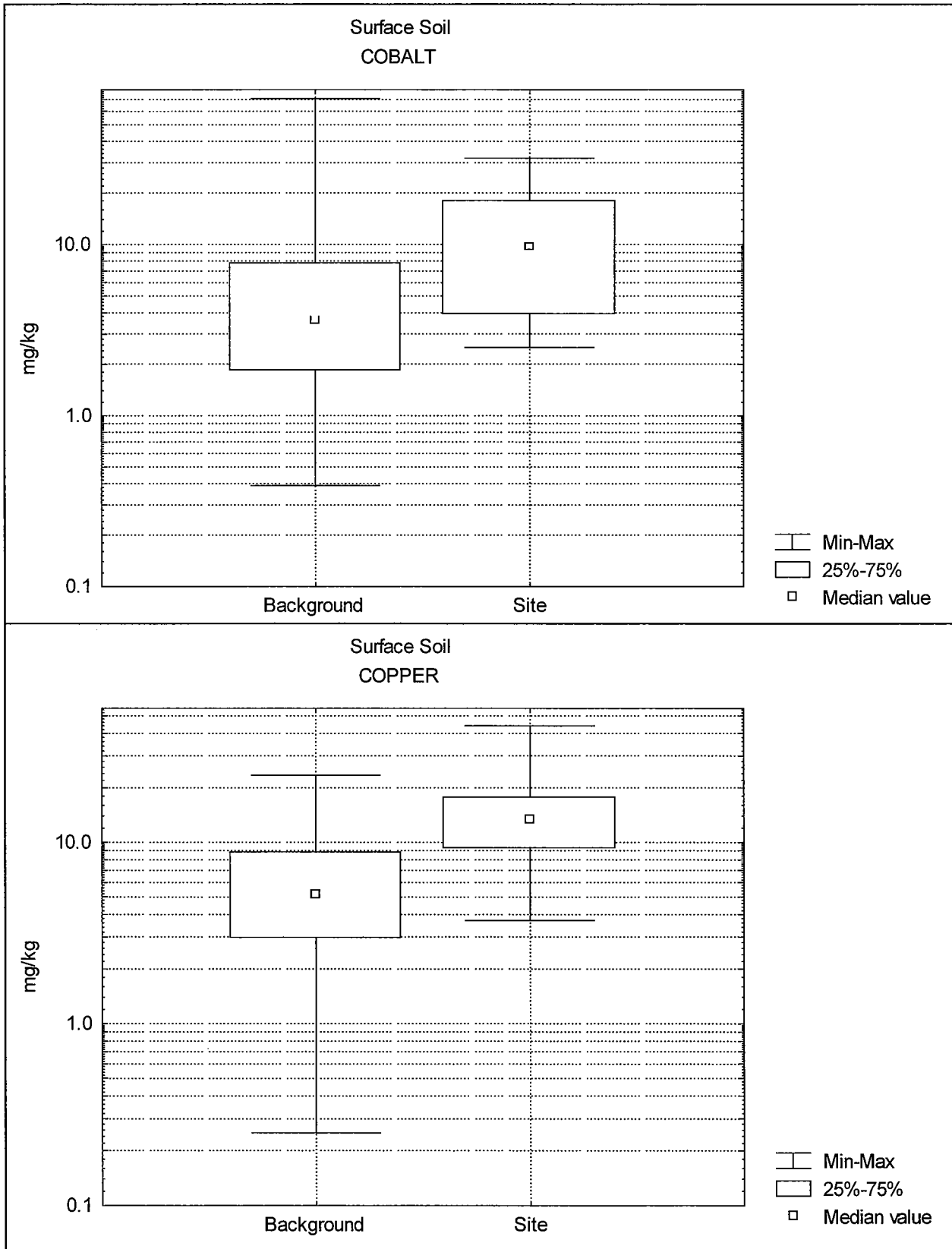


Figure 1-4

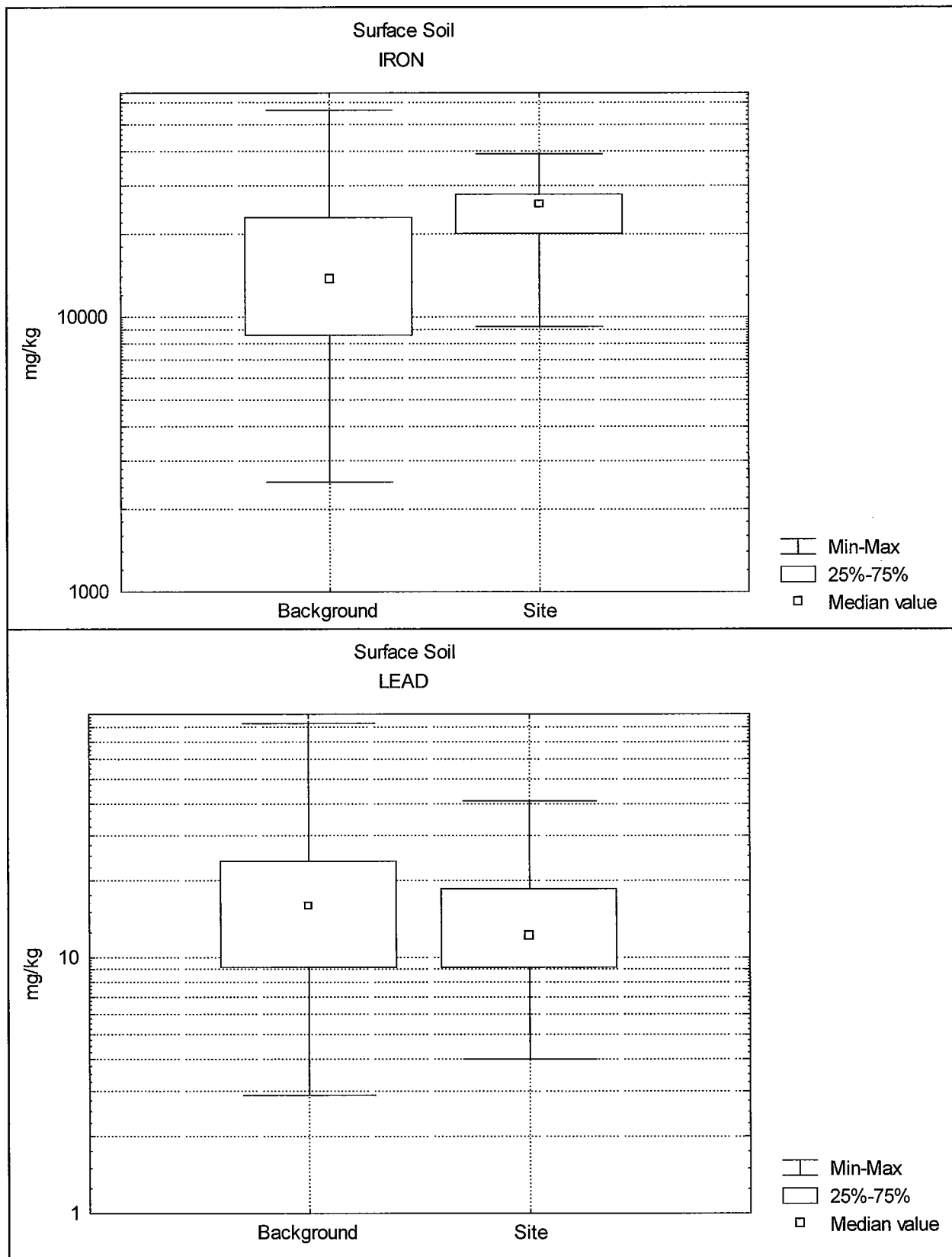


Figure 1-5

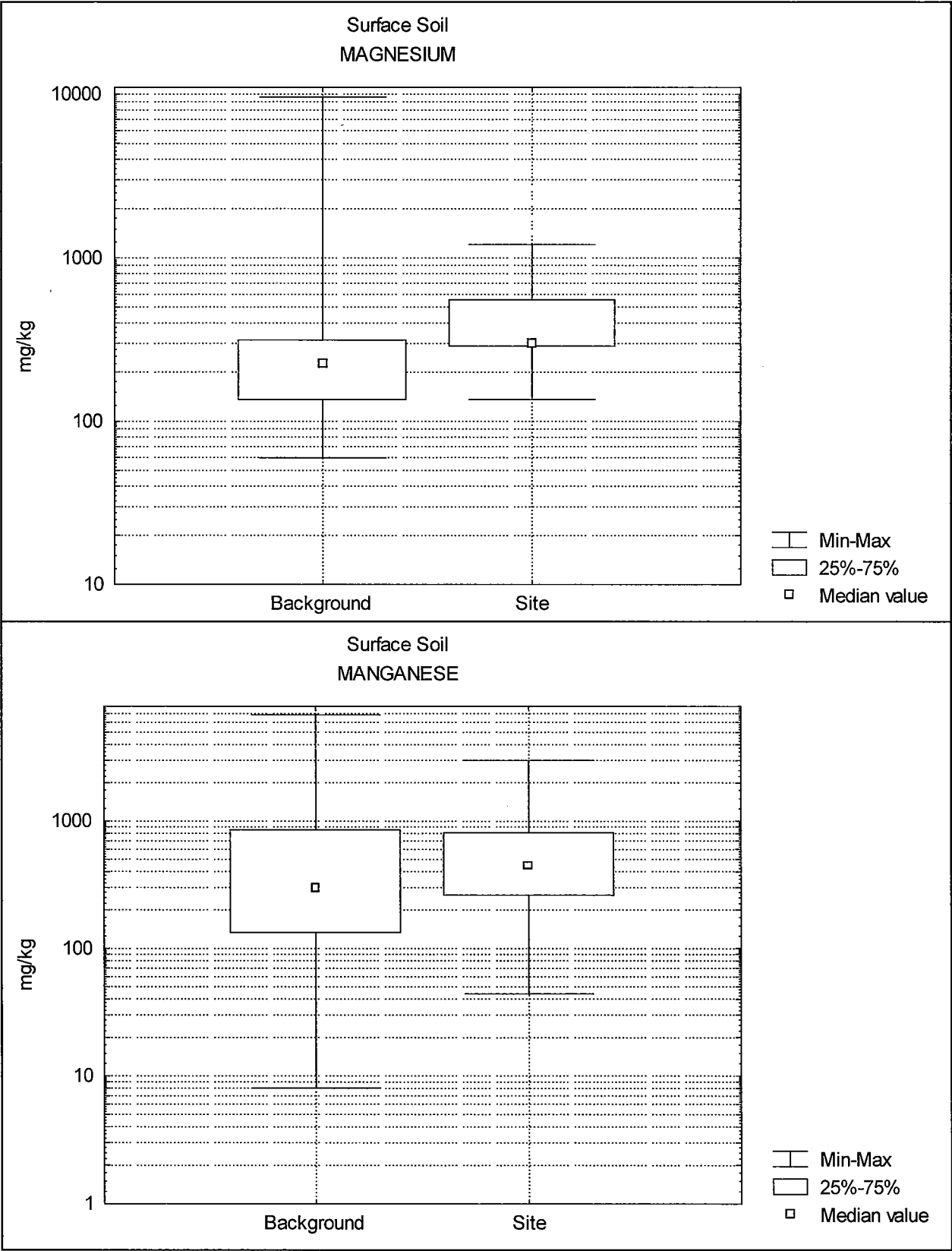


Figure 1-6

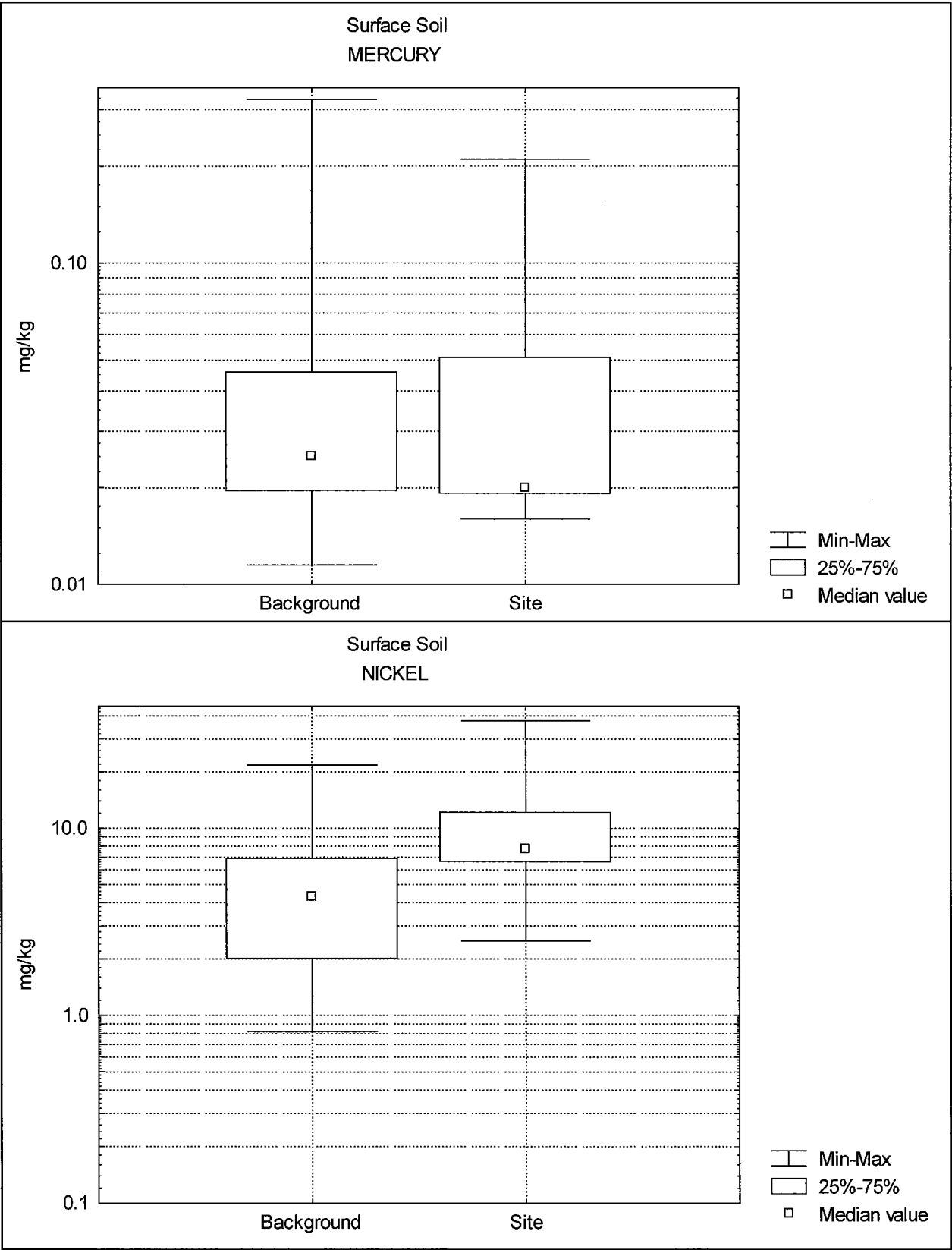


Figure 1-7

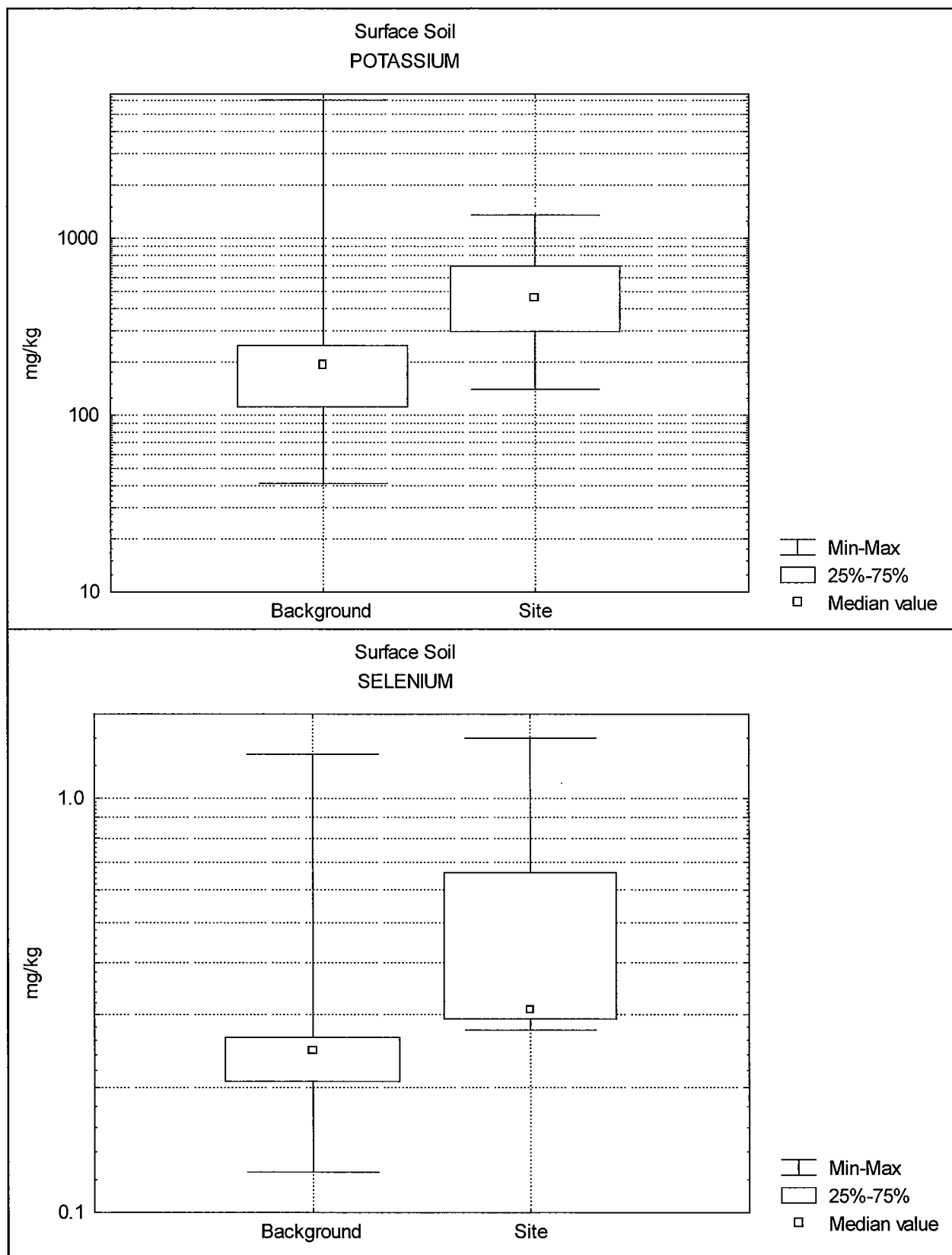


Figure 1-8

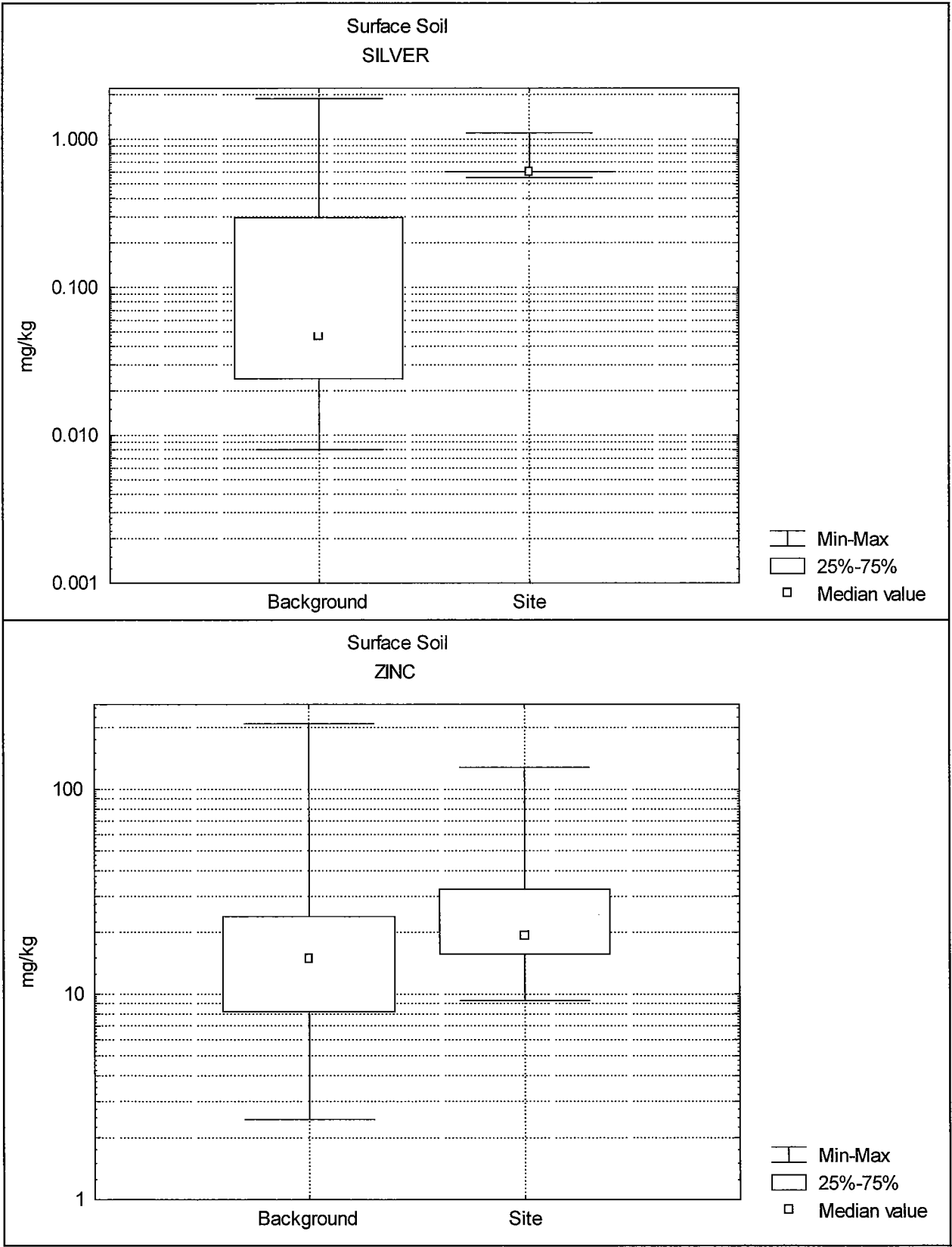


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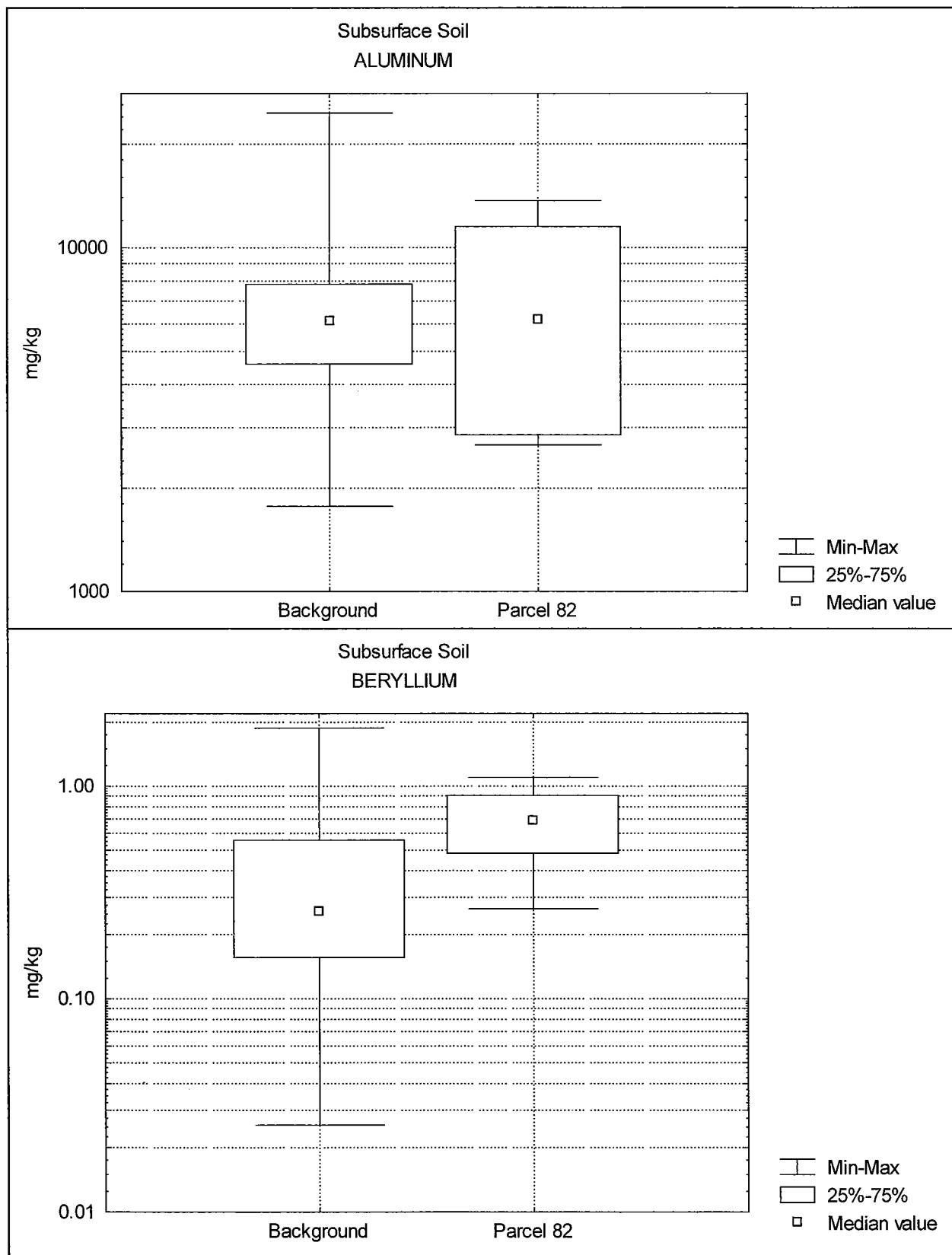


Figure 1-10

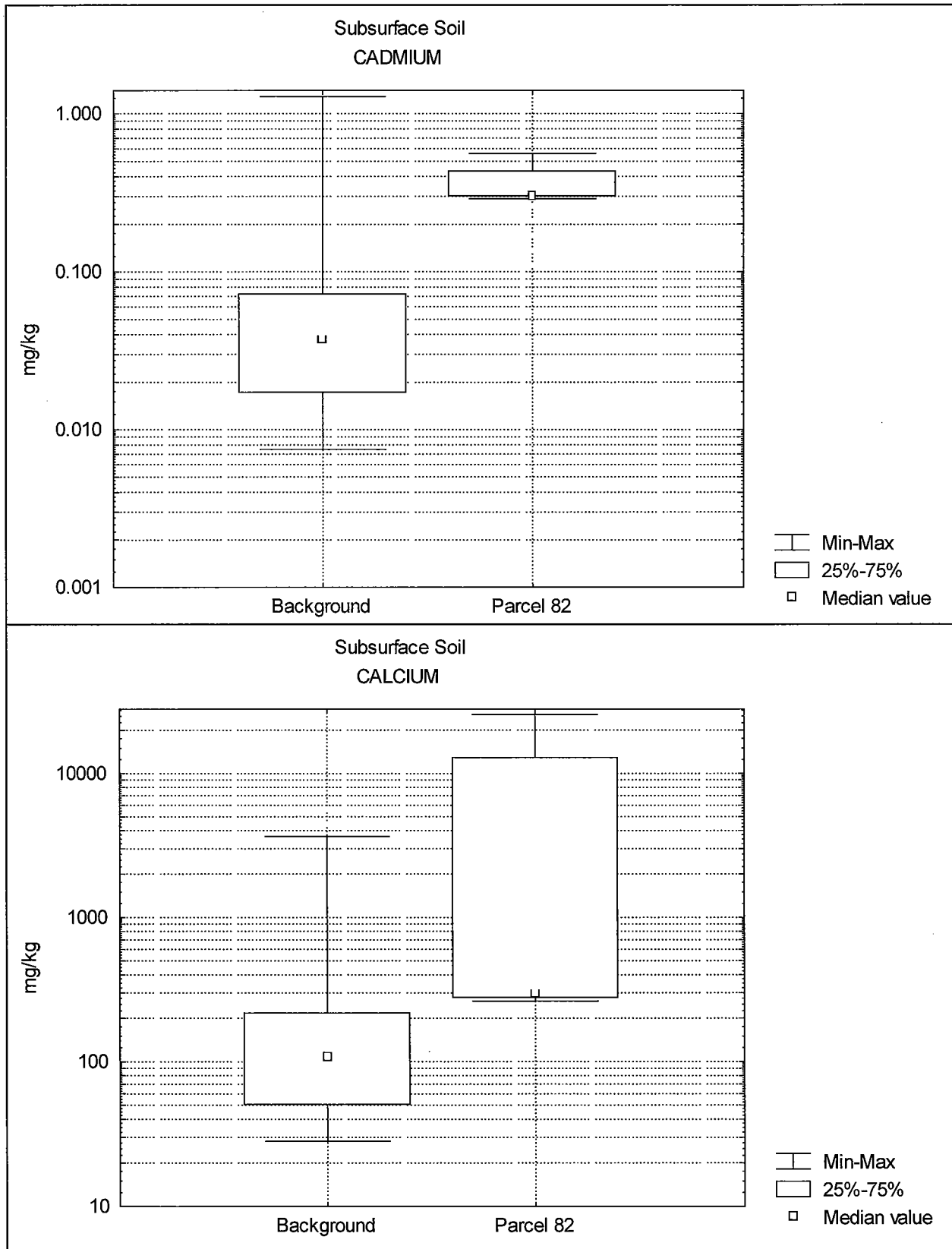


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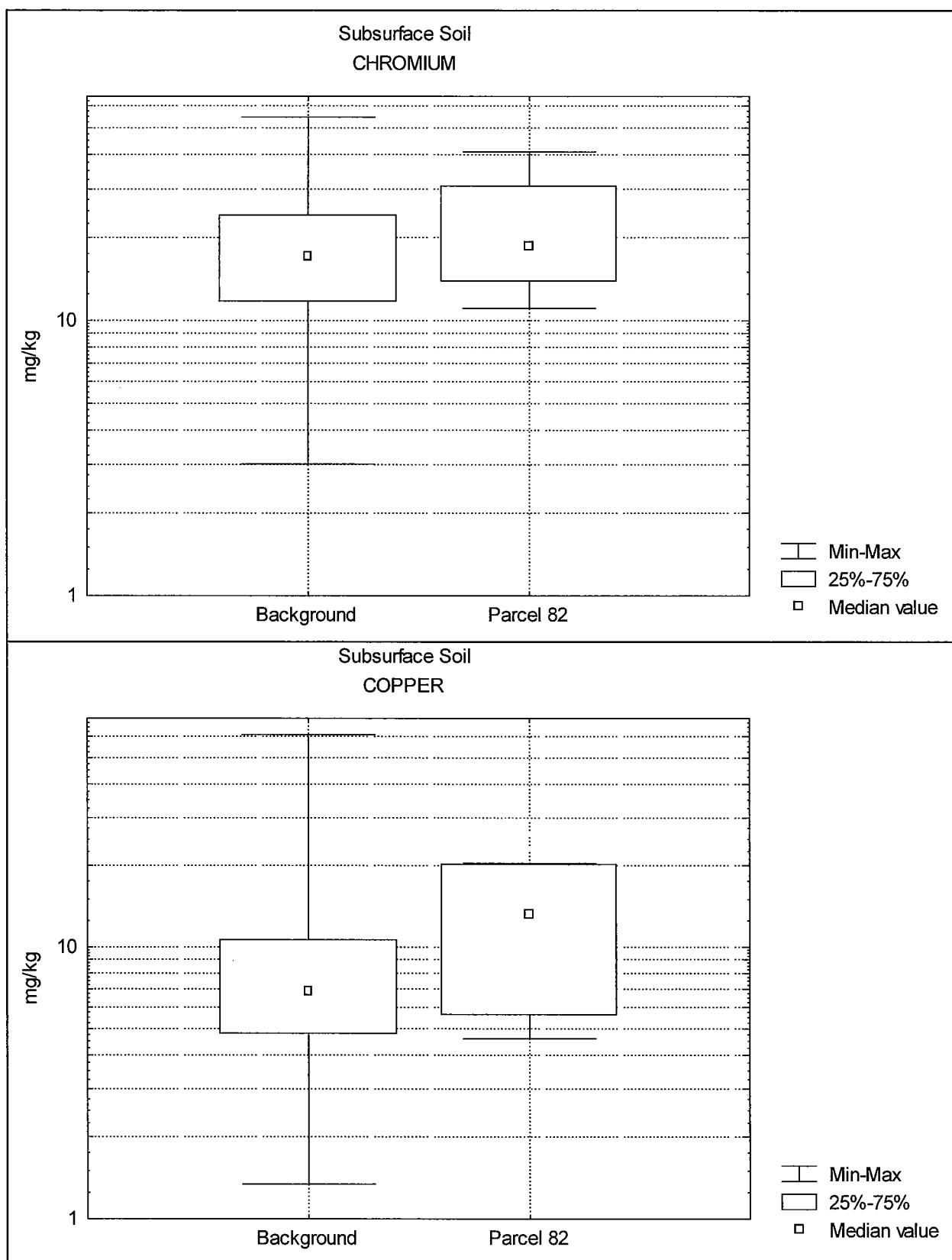


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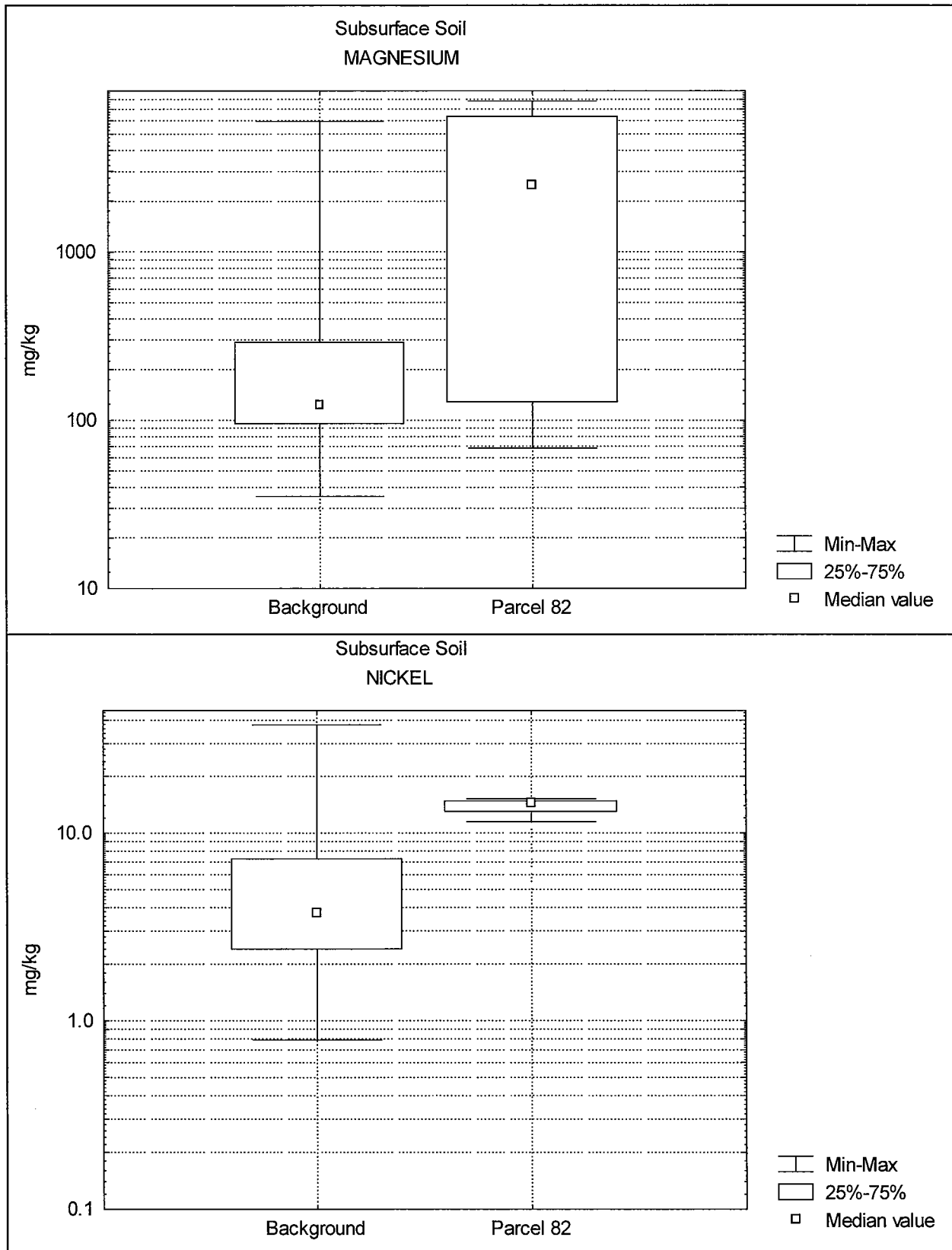


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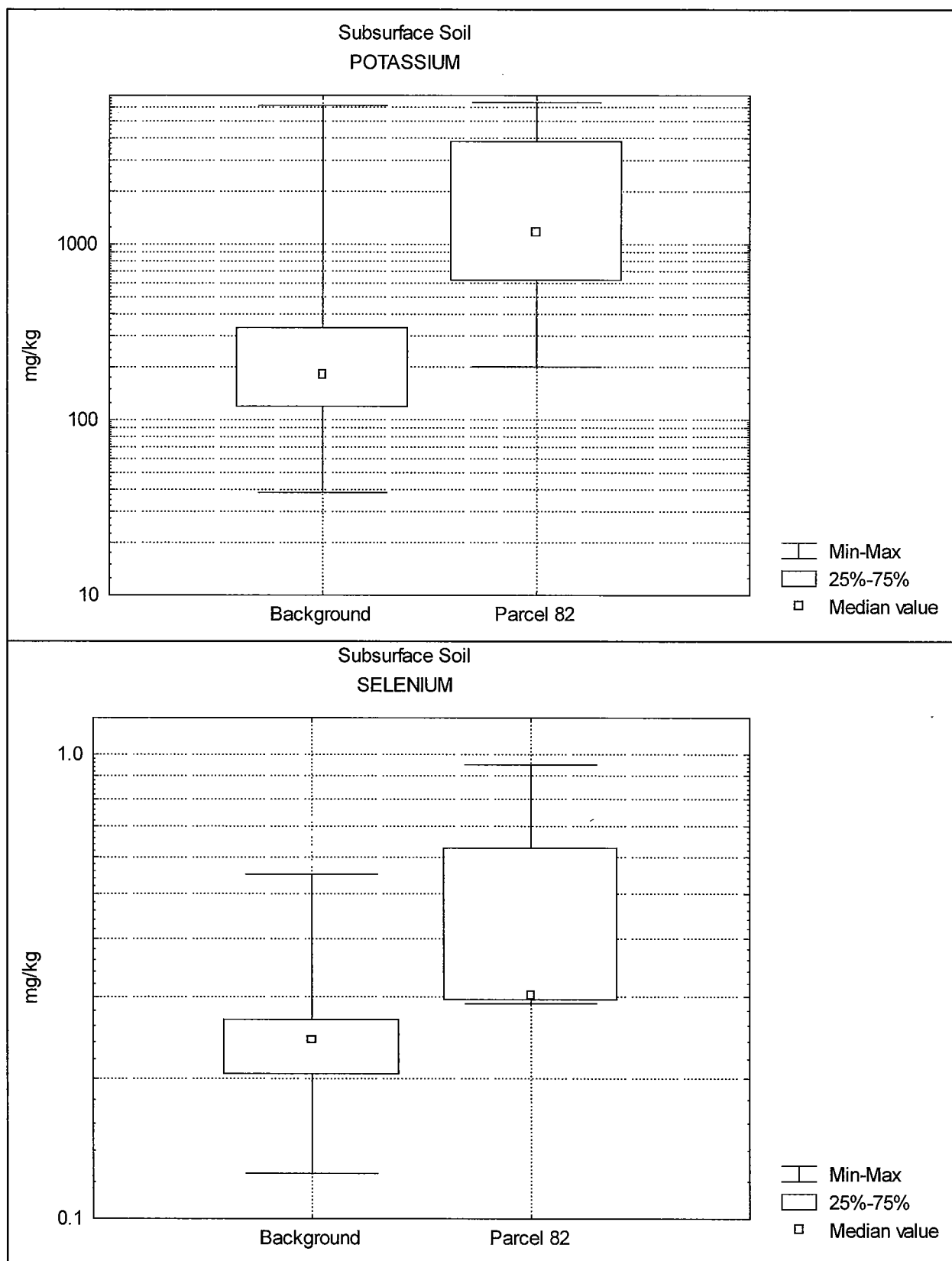


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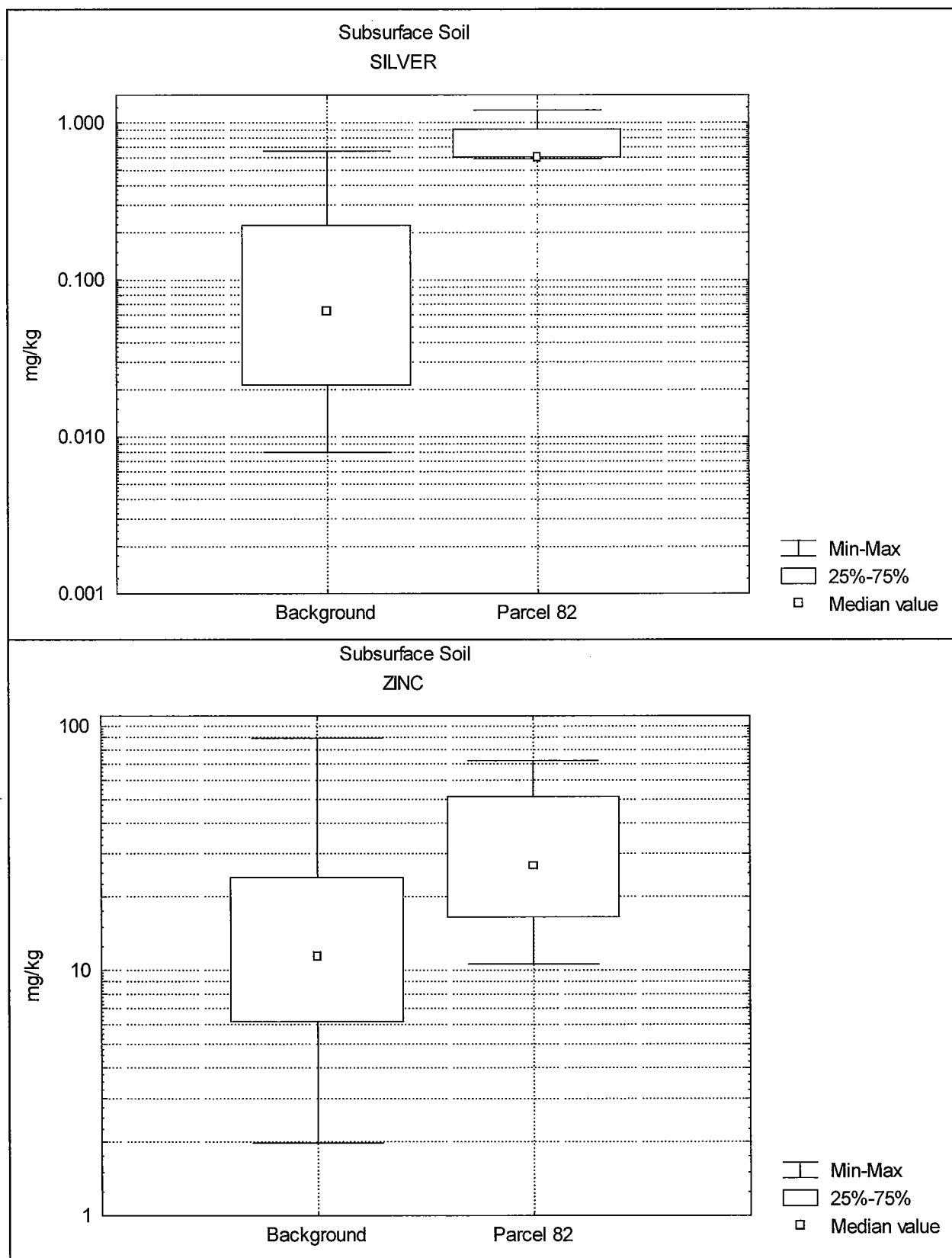


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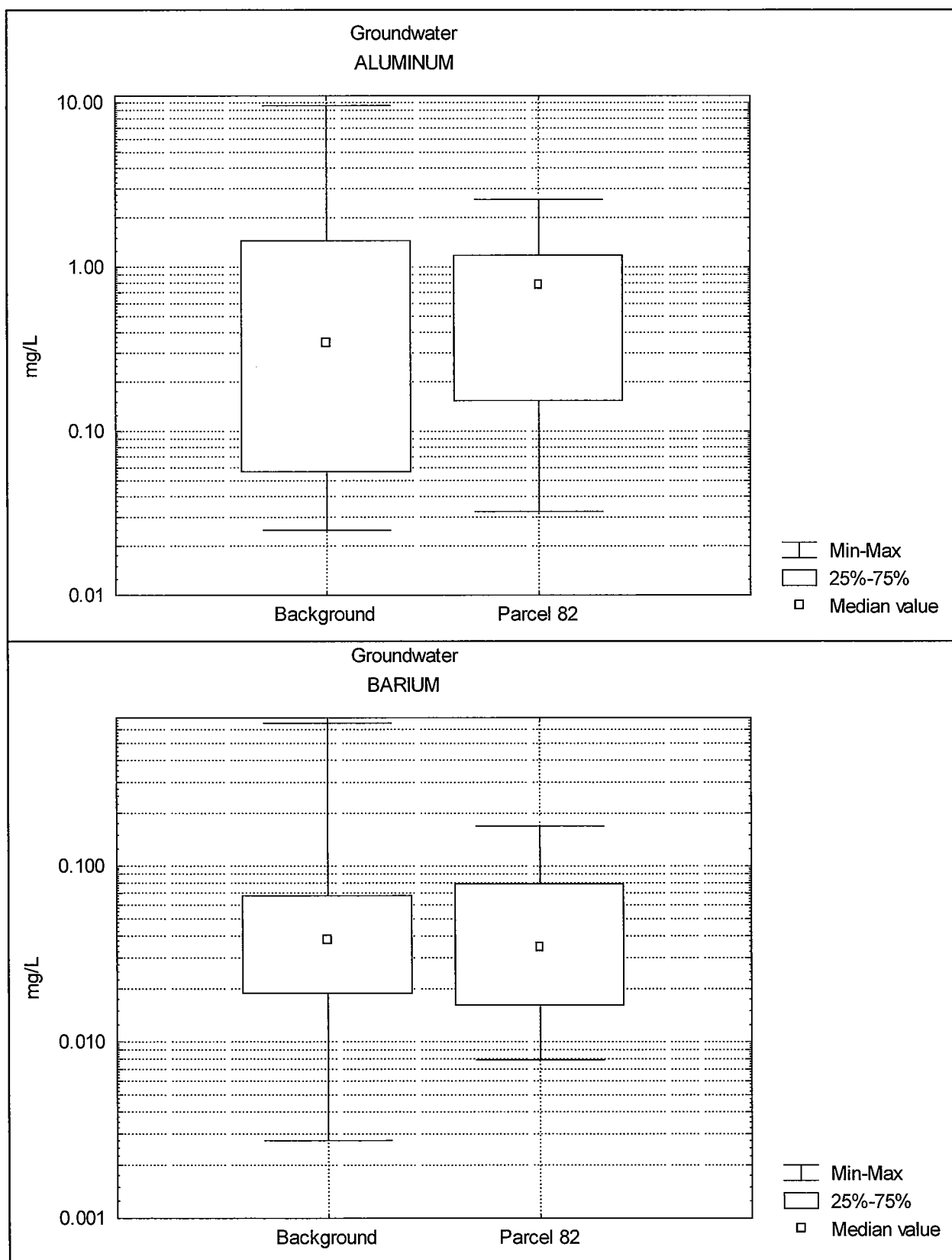


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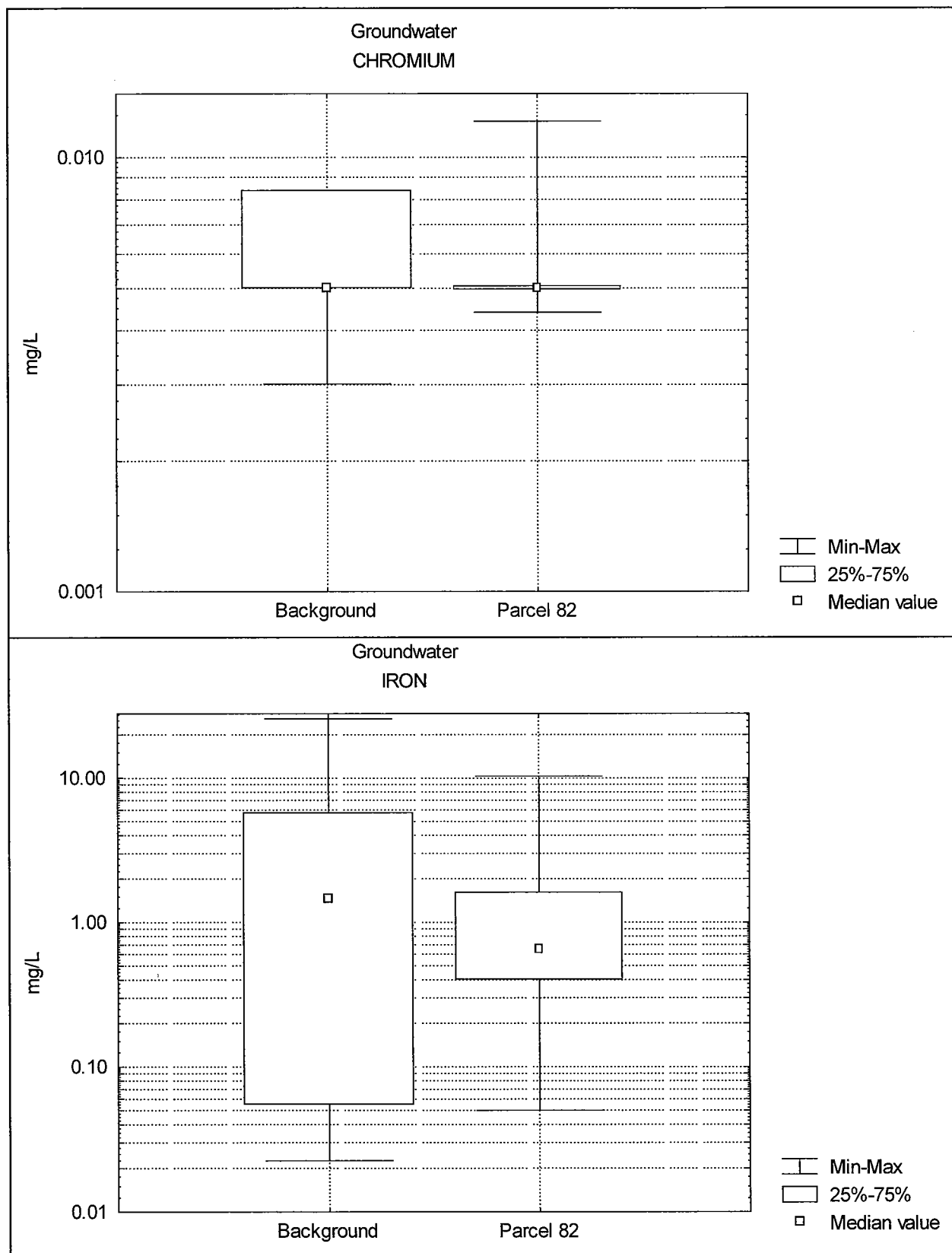


Figure 1-17

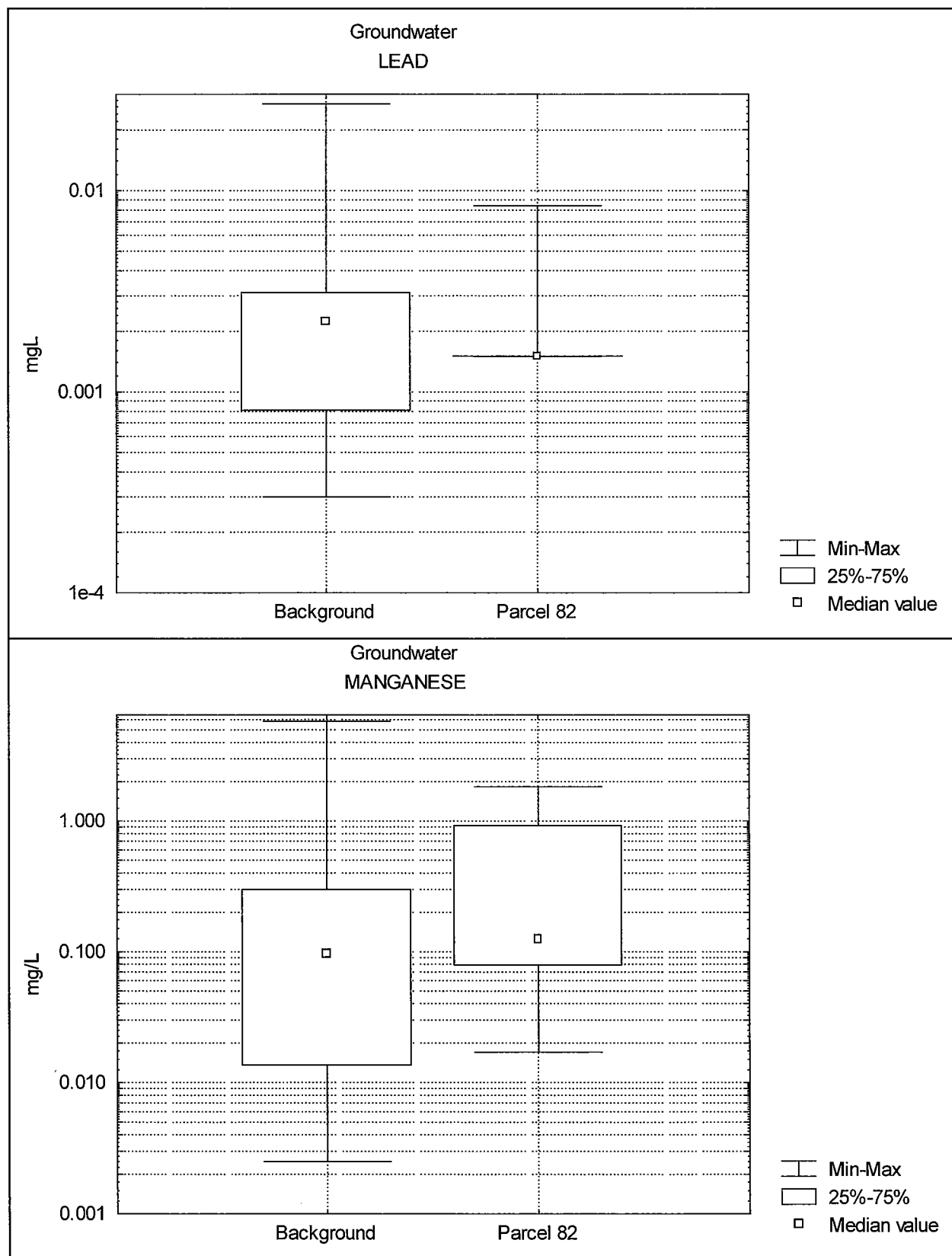


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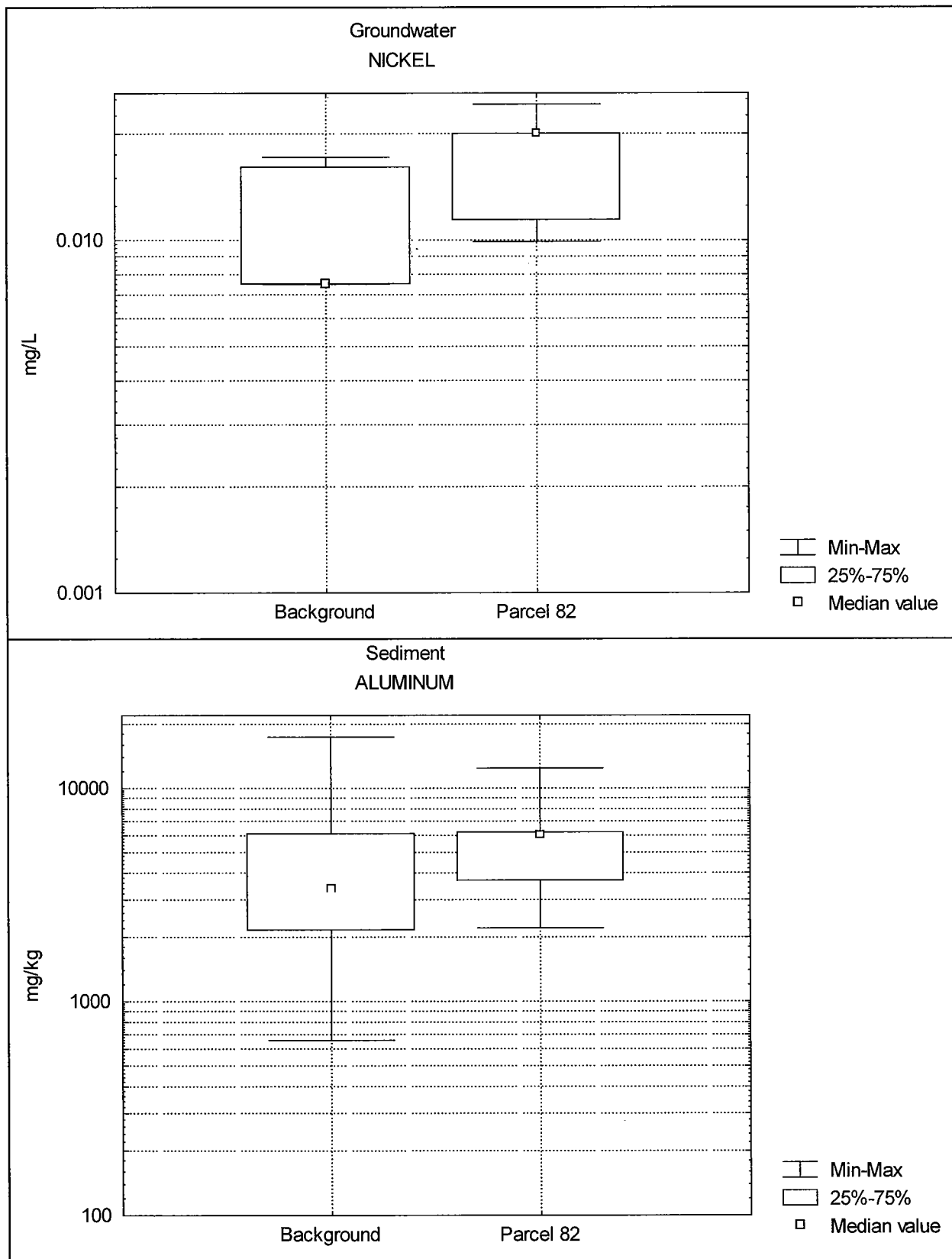


Figure 1-19

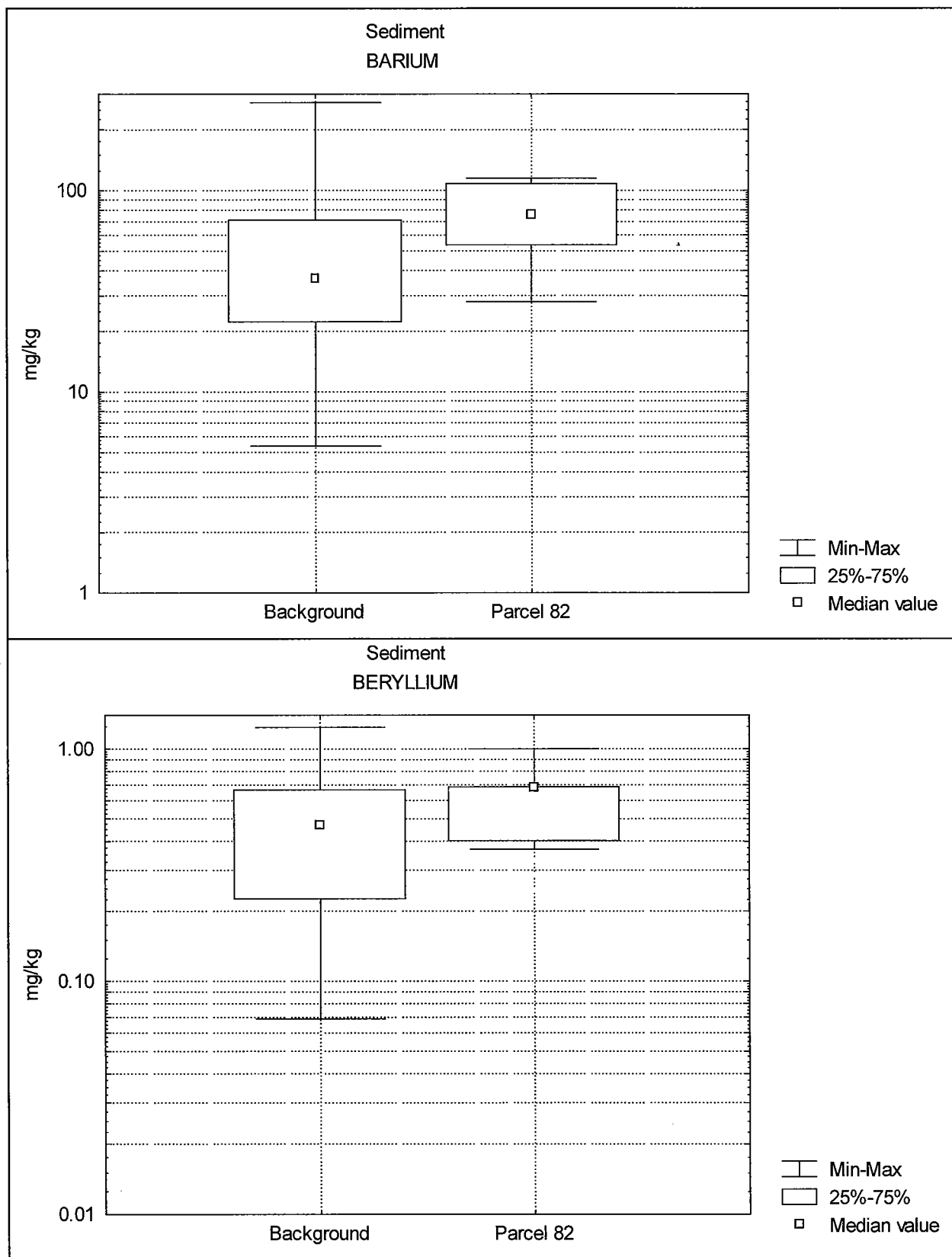


Figure 1-20

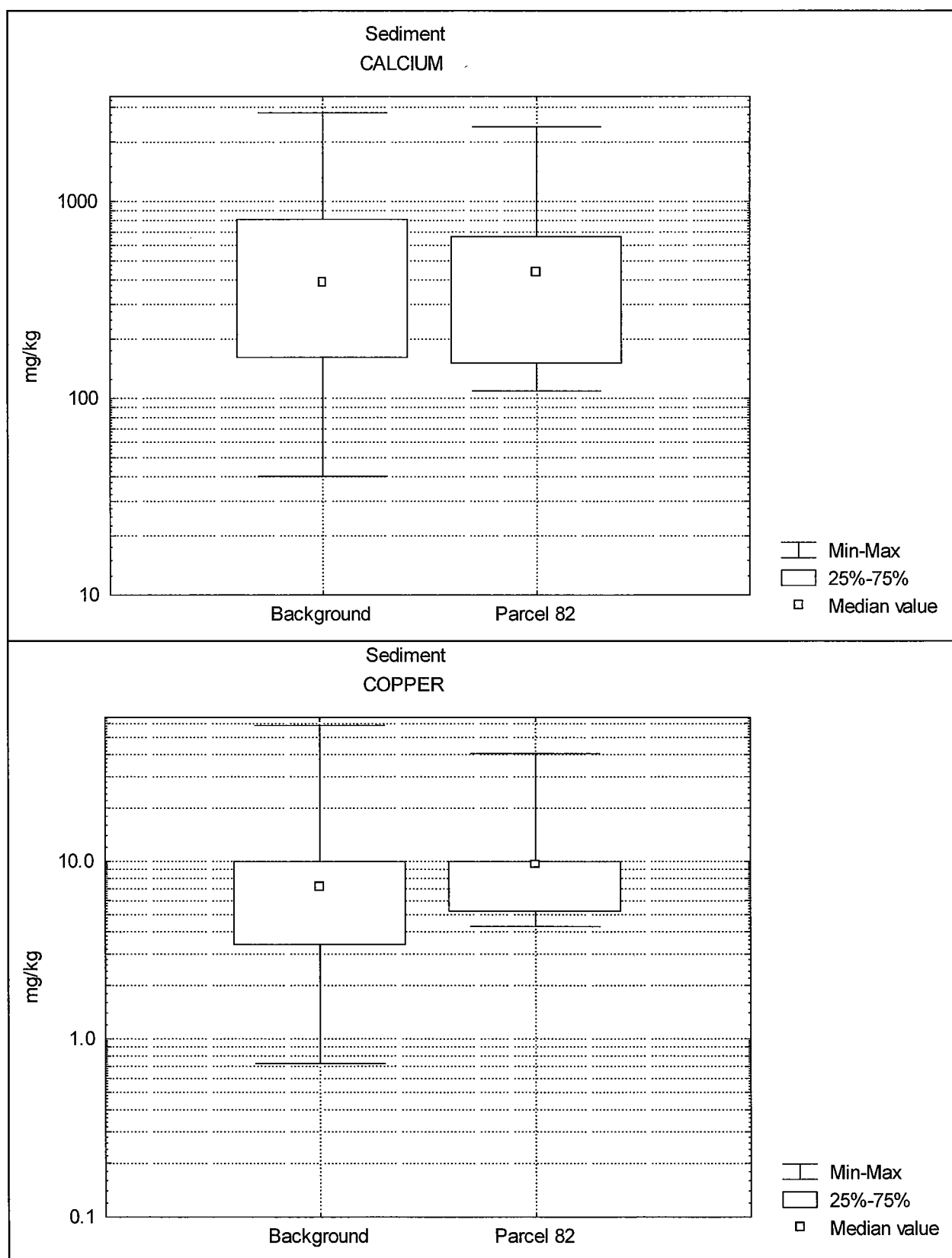


Figure 1-21

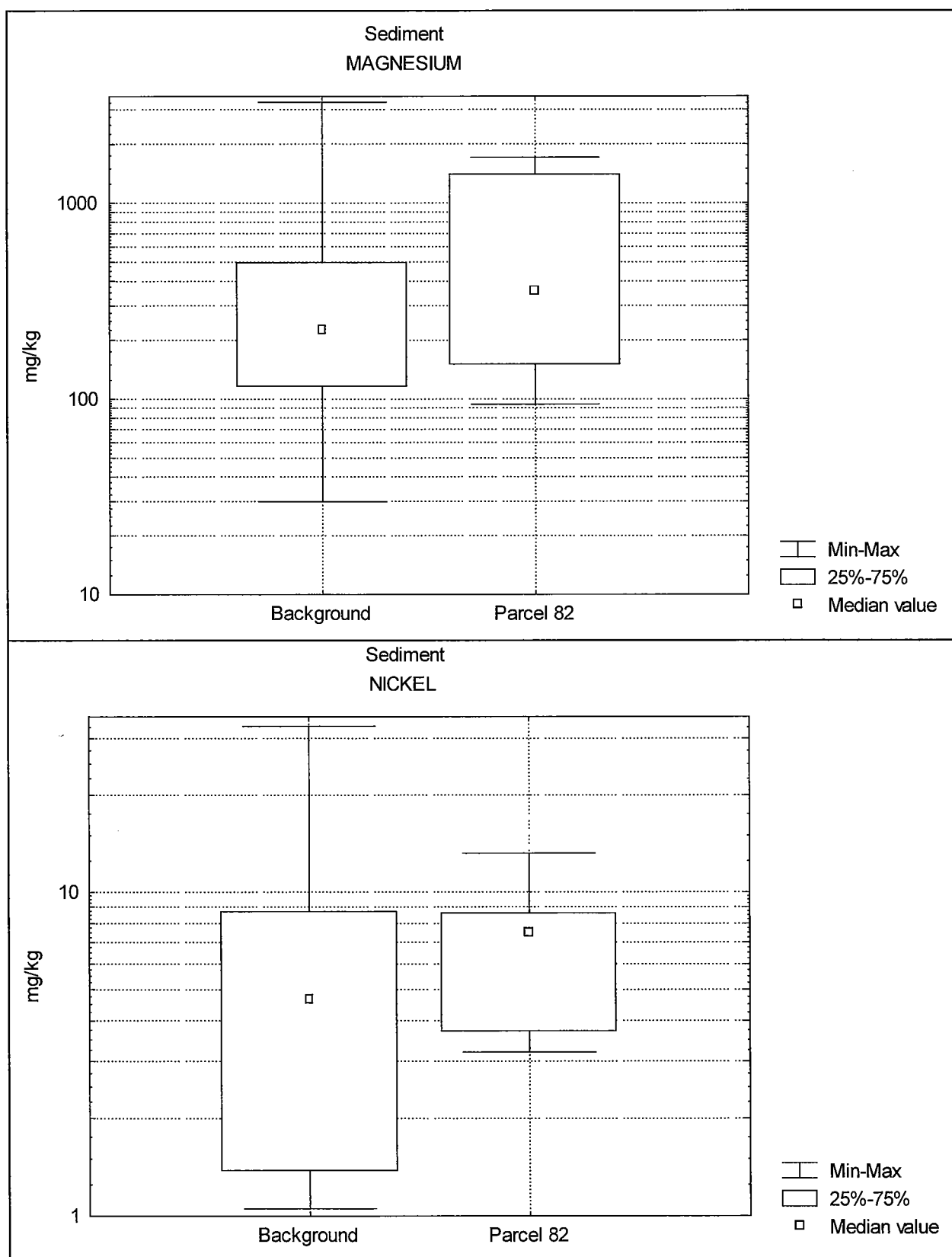


Figure 1-22

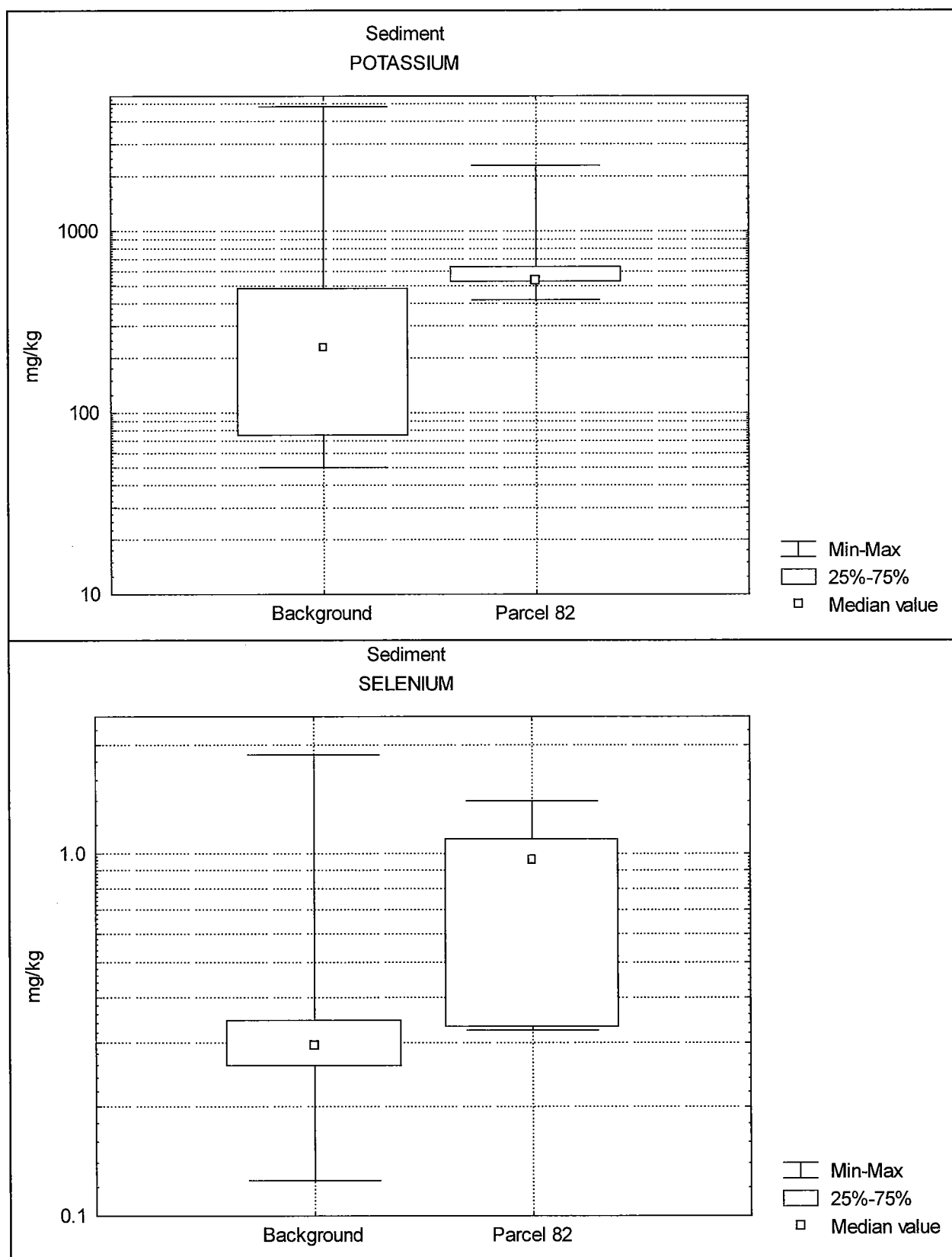


Figure 1-23

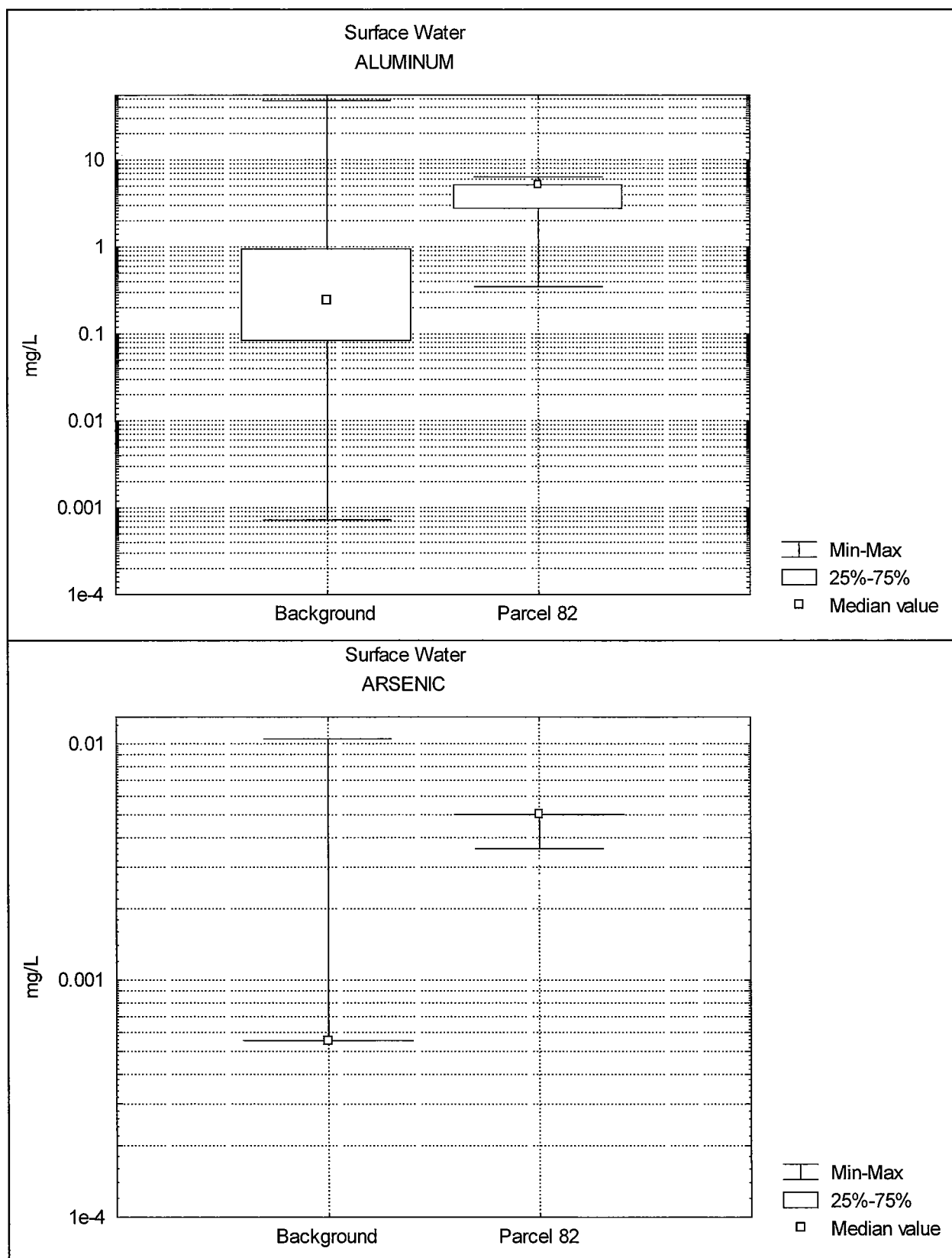
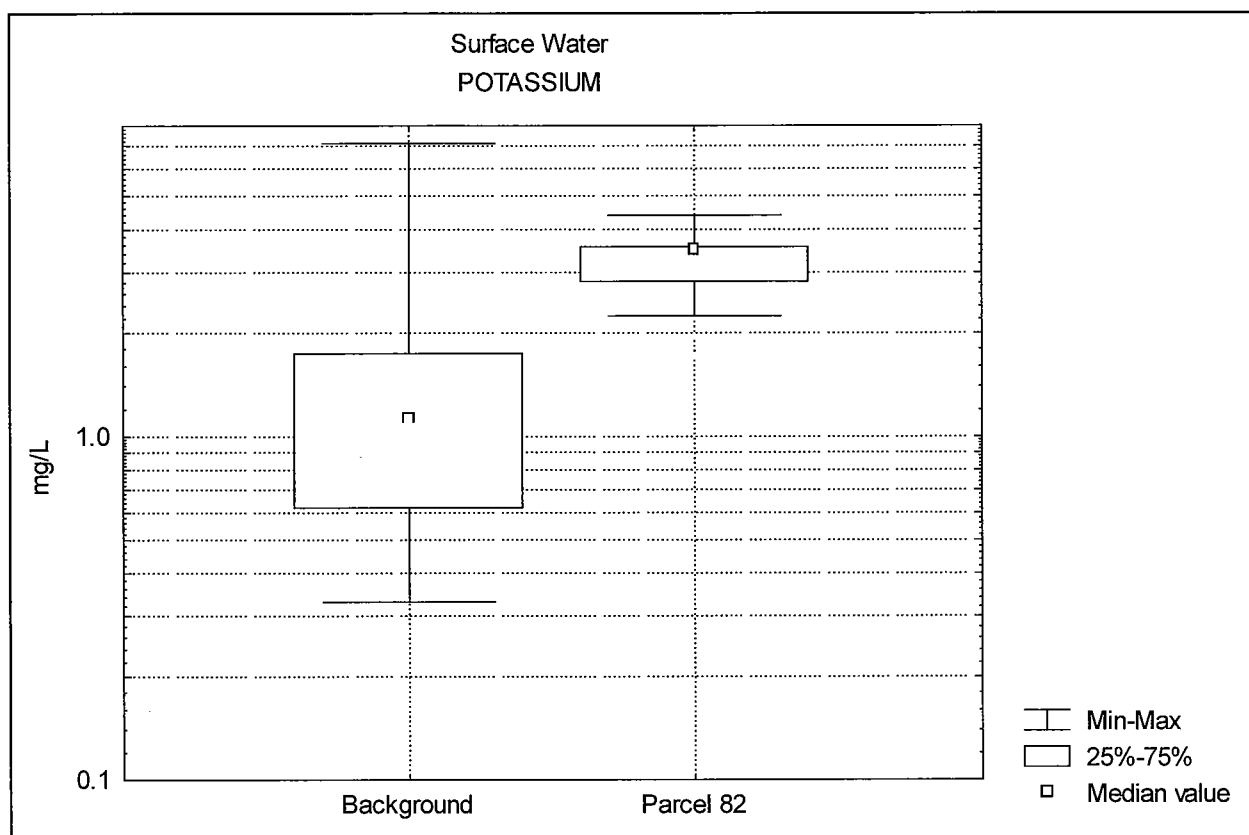


Figure 1-24



GEOCHEMICAL

Geochemical Evaluation of Metals in Soil, Sediment, and Surface Water at the Stump Dump, Parcel 82(7) Fort McClellan, Alabama

1.0 Introduction

This report provides the results of a geochemical evaluation of inorganic constituents in soil and groundwater samples from the Stump Dump, Parcel 82(7), Fort McClellan, Calhoun County, Alabama. Thirteen elements in soil, three elements in sediment, and three elements in surface water failed statistical comparison to background. A geochemical evaluation was performed to determine if the elevated concentrations are naturally occurring or if they contain a component of contamination.

Site samples included in the evaluation consist of fourteen surface soil samples (obtained from depths of 0 to 1 foot below ground surface [bgs] or 0 to 2 feet bgs) collected in November-December 1998 and March 1999; four subsurface soil samples (various depths ranging from 7 to 13 feet bgs) collected in December 1998; five sediment samples collected in January 1999; and five unfiltered surface water samples collected in January 1999. All of the site samples were analyzed for the full list of 23 target analyte list (TAL) metals. Installation-wide background data for TAL metals in soil, sediment, and surface water are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluation.

2.0 Geochemical Evaluation Methodology

Naturally occurring trace element concentrations in environmental media commonly exceed regulatory screening criteria. Trace element distributions in uncontaminated soil tend to have very large ranges (two to three orders of magnitude are not uncommon), and are highly right-skewed, resembling lognormal distributions. These trace elements are naturally associated with specific soil-forming minerals, and the preferential enrichment of a sample with these minerals will result in elevated trace element concentrations. It is thus important to be able to identify these naturally high concentrations and distinguish them from potential contamination.

If an analyte fails statistical comparison to background as described in the "Statistical Comparison of Site and Background Data for the Stump Dump, Parcel 82," then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The importance of geochemical evaluations in distinguishing between site and

background data sets has been recognized in the industry (U.S. Environmental Protection Agency, 1995; Barclift, *et al.*, 2000; U.S. Navy, 2002; Myers and Thorbjornsen, 2004). When properly evaluated, geochemistry can provide mechanistic explanations for apparently high, yet naturally occurring, constituents. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples. This section describes the geochemical evaluation techniques that were employed in the site-to-background comparisons for Range 30.

It should be noted that the geochemical evaluations rely in part on professional judgment and qualitative assessment is a necessary part of the process. Samples that plot off the linear trend on a correlation plot are certainly suspect, but because all uncertainty cannot be eliminated from the evaluation, such plots cannot be construed as definitive proof of contamination. However, anomalous samples should be flagged as suspect and their results used as a basis for further investigation, risk assessment, or remediation, as appropriate. The combination of statistical evaluations (Tiers 1 and 2) and geochemical evaluation (Tier 3) as presented in this appendix is effective in reducing the occurrences of decision errors relative to consideration of statistics or geochemistry alone.

2.1 Soil and Sediment

The geochemical evaluation is based on the natural associations of trace elements with specific minerals in the soil or sediment matrix. As an example, arsenic in most uncontaminated oxic soils is almost exclusively associated with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). (The term "iron oxide" is used here to include oxides, hydroxides, oxyhydroxides, and hydrous oxides of iron.) This association of arsenic with iron oxides is a result of the adsorptive behavior of this particular trace metal in an oxic soil environment. Arsenic is present in oxic soil pore fluid as negatively charged oxyanions (HAsO_4^{-2} , H_2AsO_4^-) (Brookins, 1988). These anions have strong affinities to adsorb on the surfaces of iron oxides, which maintain a strong positive surface charge (Electric Power Research Institute, 1986). If a soil sample has a high percentage of iron oxides, then it is expected to have a proportionally higher concentration of arsenic.

The absolute concentrations of arsenic and iron can vary by several orders of magnitude at a site, but the arsenic/iron ratios in the samples are usually quite constant as long as no contamination is present (Daskalakis and O'Connor, 1995). If a sample has some naturally occurring arsenic plus additional arsenic from an herbicide or some other source, then it will have an anomalously high ratio relative to the other uncontaminated samples. These ratios thus serve as a powerful technique for identifying contaminated samples.

The evaluation includes the generation of plots in which detected arsenic concentrations in a set of samples are plotted on the y-axis, and the corresponding detected iron concentrations are plotted on the x-axis. The slope of a best-fit line through the samples is equal to the average arsenic/iron background ratio. If the samples with the highest arsenic concentrations plot on the same linear trend as the other samples, then it is most probable that the elevated concentrations are natural, and are caused by the preferential enrichment of iron oxides in those samples. If the site samples with elevated arsenic concentrations plot above the trend displayed by the uncontaminated samples, then there is evidence that those samples have an excess contribution of arsenic, and contamination may be indicated.

Each trace element is associated with one or more minerals in the soil matrix. Vanadium and selenium, along with arsenic, form anionic species in solution and are associated with iron oxides, which maintain a positive surface charge. Divalent metals such as barium, cadmium, lead, and zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. These trace elements would be evaluated against aluminum, which is a major component of clay minerals. Manganese oxides also have an affinity to adsorb divalent cations such as barium, cobalt, and lead (Kabata-Pendias, 2001). These trace elements would be evaluated against manganese.

2.2 Groundwater and Surface Water

Elevated concentrations of inorganic constituents in groundwater and surface water samples may be due to naturally high dissolved concentrations, the presence of suspended particulates in the samples, reductive dissolution, or contamination resulting from site activities. This section discusses the major geochemical processes considered during the evaluation of groundwater and surface water analytical data.

Effects of Suspended Particulates. The presence of trace elements adsorbed on suspended particulates can greatly increase trace element concentrations as reported by an analytical laboratory. These adsorbed trace elements are not in true solution, and can be removed by settling or filtration. The same concepts involved in the evaluation of soil and sediment data also apply to groundwater and surface water data: samples containing trace elements adsorbed on suspended clay particulates should show a positive correlation with aluminum concentrations, and samples containing trace elements adsorbed on suspended iron oxides should show a positive correlation with iron concentrations. These correlations are evaluated by generating x-y

plots of the concentrations of an elevated trace metal versus aluminum or iron (depending on the trace element).

The most common suspended particulates in groundwater samples are clay minerals; hydrous aluminum oxides ($\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$) and hydroxides [$\text{Al}(\text{OH})_3$]; and iron oxide (Fe_2O_3), iron hydroxide [$\text{Fe}(\text{OH})_3$], and iron oxyhydroxide ($\text{FeO} \cdot \text{OH}$) minerals, collectively referred to as “iron oxides.” All clay minerals contain aluminum and have low solubilities over a neutral pH range of 6 to 8. Measured concentrations of aluminum in excess of ~1 milligram per liter (mg/L) indicate the presence of suspended clay minerals (Hem, 1985; Stumm and Morgan, 1996), with higher aluminum concentrations being a qualitative indicator of the mass of suspended clay minerals. Iron also has a very low solubility under neutral pH and moderate to oxidizing redox conditions, so that measured iron concentrations in excess of ~1 mg/L under these conditions indicate the presence of suspended iron oxides (Hem, 1985).

The presence of suspended clay or iron oxides in groundwater samples has particular importance in the interpretation of trace element concentrations. Most clay particles maintain a negative surface charge under neutral pH conditions, and have a strong tendency to adsorb positively charged (cationic) aqueous species. Iron oxides display the opposite behavior, maintaining a positive surface charge under neutral pH conditions, and have a strong tendency to adsorb negatively charged (anionic) aqueous species.

Barium, lead, and zinc are usually present in groundwater as divalent cations and thus tend to concentrate on clay surfaces (Electric Power Research Institute, 1984; Brookins, 1988). Arsenic, selenium, and vanadium are usually present under oxidizing conditions as oxyanions, and thus tend to concentrate on iron oxide surfaces (Bowell, 1994; Hem, 1985; Pourbaix, 1974; Brookins, 1988).

Chromium can be present in groundwater as a mixture of aqueous species with different charges, depending on pH (Electric Power Research Institute, 1984). The positive, neutral, and negative charges on these species result in the distribution of chromium on several different types of sorptive surfaces, including clay and iron oxide minerals.

As an example, the concentrations of zinc (y-axis) would be plotted against aluminum (x-axis). If all of the samples display a common linear trend, then it is most likely that the zinc concentrations are due to the presence of suspended clay minerals in the samples. The slope of a best-fit line through the points is equal to the average zinc/aluminum ratio. If some samples plot

above the linear trend established by the other samples, then those samples have an anomalously high zinc/aluminum ratio, and most likely contain excess zinc that cannot be explained by these natural processes.

Alternative techniques for assessing the effects of suspended particulates on trace element concentrations are the evaluation of correlations of trace element concentrations versus turbidity, and comparison of analyses of filtered versus unfiltered splits of samples. Turbidity measurements are qualitative, and do not distinguish between suspended clay minerals, iron oxides, and natural organic material, so this approach lacks the resolution provided by trace element versus aluminum or trace element versus iron correlations.

If the concentrations of trace elements in unfiltered samples are correlated with aluminum or iron, then they are most likely adsorbed to the surfaces of suspended particulates. If these correlations are linear, then the elevated concentrations are most likely natural.

Effects of Reductive Dissolution. Iron and manganese oxides concentrate several trace elements such as arsenic, selenium, and vanadium on mineral surfaces, as discussed above. In soils and sedimentary aquifers, these elements are almost exclusively associated with iron and manganese oxide minerals and grain coatings, as long as the redox conditions are moderate to oxidizing.

The release of organic contaminants such as fuels or chlorinated solvents can establish local reducing environments caused by anaerobic microbial degradation of the organic compounds. The establishment of local reducing conditions can drive the dissolution of iron and manganese oxides, which become soluble as the redox potential drops below a threshold value. Dissolution of these oxide minerals can mobilize the trace elements that were adsorbed on the oxide surfaces, which is a process termed “reductive dissolution.” Several investigations have documented the mobilization of arsenic, selenium, and other trace elements under locally reducing redox conditions (Sullivan and Aller, 1996; Nickson, *et al.*, 2000; Belzile, *et al.*, 2000).

Evidence for reductive dissolution would be a correlation between elevated trace elements (arsenic, selenium, and vanadium in particular) versus lower redox conditions. Low redox conditions can be identified by local depressions in oxidation-reduction potential (ORP) or dissolved oxygen (DO) measurements, or the presence of reducing gases such as hydrogen, methane, ethane, or ethene. Anaerobic microbes can also reduce sulfate to sulfide and nitrate to ammonia, resulting in local depressions in sulfate and nitrate concentrations, and local detections

of sulfide and ammonia. In areas impacted by chlorinated solvents, additional evidence for the establishment of anaerobic reducing conditions is the presence of *cis*-1,2-dichloroethene and/or vinyl chloride, which are reductive dechlorination products resulting from the microbial degradation of trichloroethene or tetrachloroethene under anaerobic conditions.

3.0 Results of the Geochemical Evaluation for Multiple Elements in Soil

This section presents the results of the geochemical evaluation of barium, beryllium, calcium, cobalt, copper, iron, magnesium, mercury, nickel, potassium, selenium, silver, and zinc in soil samples from Parcel 82(7). Correlation plots are provided in Attachment 1.

Barium

Manganese oxides have an affinity to adsorb divalent cations such as barium and cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. The site and background samples form a collinear trend in a plot of barium versus manganese (Figure 1). The site samples with the highest barium concentrations also contain proportionally higher manganese concentrations, and lie on the trend established by the other samples. These observations indicate that barium in the site samples is associated with manganese oxides at a relatively constant ratio, and is natural.

Conclusion

Barium detected in the site soil samples is naturally occurring.

Beryllium

Beryllium concentrations in soil are commonly controlled through adsorption on iron oxides (Vesely, *et al.*, 2002), so a positive correlation between beryllium and iron would be expected for uncontaminated samples. A plot of beryllium versus iron is provided in Figure 2. The background samples and most of the site samples form a generally linear trend, and most of the site samples with high beryllium concentrations also have high iron. Beryllium in these samples has a natural source. Surface soil sample FX0025, however, contains the highest beryllium concentration of both data sets (2.9 mg/kg) but only moderate iron (as well as only low aluminum and moderate manganese), and lies above the trend established by the other samples. There may be a component of contamination in this sample, which was collected from location FTA-82-DEP05. It should be noted that this anomalous concentration is only slightly higher than the background maximum of 2.03 mg/kg, so any contamination in the sample is not significant.

Conclusion

The beryllium concentration in sample FX0025 is slightly elevated with respect to the major elements and may contain a component of contamination. Beryllium detected in the other surface soil samples and all of the subsurface soil samples is naturally occurring.

Calcium

Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of calcium versus magnesium is provided in Figure 3. Most of the site and background samples exhibit a generally linear trend with a positive slope. The site samples with the highest calcium concentrations also contain proportionally higher magnesium, and lie on the linear trend. This indicates a natural source for the elevated calcium in the site samples. One site subsurface sample contains elevated magnesium (4,770 mg/kg) but low calcium (73.1 mg/kg), and lies below the trend established by the other samples. The calcium concentration of this sample, however, is well within the background range.

Conclusion

Calcium detected in the site soil samples is naturally occurring.

Cobalt

Manganese oxides have an affinity to adsorb divalent cations such as barium and cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. The site and background samples form a collinear trend in a plot of cobalt versus manganese (Figure 4). The site samples with high cobalt concentrations also contain proportionally higher manganese, and lie on the trend established by the other samples. These observations indicate that cobalt in the site samples is associated with manganese oxides at a relatively constant ratio, and is natural.

Conclusion

Cobalt detected in the site soil samples is naturally occurring.

Copper

Copper in soil has an affinity to adsorb on the surfaces of minerals such as clays and iron oxides (Kabata-Pendias, 2001). The site and background samples form a common linear trend with a positive slope in a plot of copper versus iron (Figure 5). The site samples with high copper concentrations also exhibit proportionally higher iron, and lie on the background trend. This indicates that copper in the site samples is associated with iron oxides at a relatively constant ratio, and is natural.

Conclusion

Copper detected in the site soil samples is naturally occurring.

Iron

Iron is the most abundant of the 23 elements analyzed in the site soil samples, with a mean concentration of 23,641 mg/kg (2.4 weight percent). Iron oxides are common soil-forming minerals, and occur as discrete mineral grains or as coatings on silicate minerals. Aluminum is a primary component of other common soil-forming minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003).

Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes. A plot of aluminum versus iron concentrations provides a

qualitative indicator of the relative abundance of these minerals in site soil (Figure 6). For both soil intervals, the site iron concentrations lie within the background range of iron concentrations. Many of the site samples with high iron also contain proportionally higher aluminum, and lie on the general background trend. There are several site samples with high iron but low aluminum, and which lie below the linear trend. There are also some background samples with similarly low Al/Fe ratios, however, so it is likely that these samples reflect the natural variability in Al/Fe ratios of Ft. McClellan soils. All of these observations indicate a natural source for aluminum and iron in the site samples. It is important to note that iron oxides and clays adsorb specific trace elements (as discussed in Section 2.1), so samples that plot on the upper end of the trend in Figure 6 are expected to contain proportionally higher concentrations of trace elements.

Conclusion

Iron detected in the site soil samples is naturally occurring.

Magnesium

As noted in the Calcium evaluation, calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals, so positive correlations between calcium and magnesium are often observed in soil samples (Figure 3). Magnesium is also a common component of minerals such as clays and micas, which contain aluminum as a primary constituent, so positive correlations between magnesium and aluminum are also expected. A plot of magnesium versus aluminum reveals a generally linear trend for most of the background samples, and the site samples lie on the background trend (Figure 7). As observed in Figures 3 and 7, the site samples with the highest magnesium concentrations also exhibit proportionally higher aluminum or calcium content. These observations indicate a natural source for the elevated magnesium in the site samples.

Conclusion

Magnesium detected in the site soil samples is naturally occurring.

Mercury

Mercury concentrations in soil are commonly controlled through organic complex formation (Kabata-Pendias, 2001), so weak correlations between mercury and iron or mercury and aluminum are often observed, even in uncontaminated soil samples. The background samples form a generally linear trend with a positive slope in a plot of mercury versus aluminum (Figure 8). The site sample with the highest mercury concentration also has the highest aluminum and lie on this trend. These observations indicate that the mercury in the site samples is associated with clays at ratios consistent with those of the background samples, and is natural.

Conclusion

Mercury detected in the site soil samples is naturally occurring.

Nickel

Nickel is commonly associated with iron oxides in soils (Kabata-Pendias, 2001), so a positive correlation between nickel and iron is expected for uncontaminated samples. A plot of nickel versus iron reveals a generally linear trend with a positive slope for the background samples, and all of the site samples lie on this trend (Figure 9). The site samples with high nickel

concentrations are also characterized by high iron content, and lie on the background trend. Nickel in the site samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural.

Conclusion

Nickel detected in the site soil samples is naturally occurring.

Potassium

Potassium and magnesium are common constituents of soil-forming minerals such as clays. Most of the background samples form a generally linear trend in a plot of potassium versus magnesium, and the site samples lie on this trend (Figure 10). The site sample with the highest potassium also has proportionally higher magnesium, and lies on the trend established by the other samples. These observations indicate a natural source for potassium in the site samples.

Conclusion

Potassium detected in the site soil samples is naturally occurring.

Selenium

As explained in Section 2.1, selenium has a strong affinity to adsorb on iron oxides in oxic soils, so a positive correlation between selenium and iron is expected for uncontaminated soil samples. Comparison to background is hindered because of the high percentage of nondetects in the background data set. The site surface soil samples form a linear trend with a positive slope in a plot of selenium versus iron, and one of the two background samples with detectable selenium lies on this trend (Figure 11). The single site subsurface soil sample with detectable selenium (0.95 mg/kg) lies above the linear trend, but there is a background sample with a higher selenium concentration (1.28 mg/kg) and a similarly high Se/Fe ratio. These two samples most likely reflect the natural variability in Se/Fe ratios in Ft. McClellan soils. All of these observations indicate a natural source for selenium in the site samples.

Conclusion

Selenium detected in the site soil samples is naturally occurring.

Silver

A plot of silver versus iron is provided in Figure 12. The four site samples with detectable silver have higher concentrations than most of the background samples, but they are also characterized by high iron. It is likely that these site samples are preferentially enriched in iron oxides and associated trace elements, and that the silver is natural. It is important to note that two of the four of the site detections are estimated ("J"-qualified) values below the reporting limit, and that such values are highly uncertain. In comparison, the background detections are mostly unestimated concentrations ranging from 0.019 to 1.87 mg/kg, with a mean of 0.128 mg/kg (14 of the 82 background samples are estimated values). Additionally, the site samples are characterized by higher reporting limits relative to the background samples: the site reporting limits range from 1.1 to 1.3 mg/kg, with a mean of 1.18 mg/kg, whereas the reporting limits for the background nondetects range from 0.016 to 1.2 mg/kg, with a mean of 0.293 mg/kg [reporting limit data are unavailable for the background detected concentrations]. The uncertainty associated with the estimated site concentrations, combined with the difference (up

to two orders of magnitude) in reporting limits between the data sets, likely explains why the site samples do not exhibit the same Ag/Fe ratios exhibited by most of the background samples.

Conclusion

Silver detected in the site soil samples is naturally occurring.

Zinc

Zinc commonly substitutes for magnesium in silicate minerals (Kabata-Pendias, 2001), so a positive correlation between zinc and magnesium would be expected for uncontaminated samples. A plot of zinc versus magnesium is provided in Figure 13. The site and background samples form a common linear trend with a positive slope. The site samples with the highest zinc also contain proportionally higher magnesium, and lie on the linear trend. This indicates a natural source for zinc in the site samples.

Conclusion

Zinc detected in the site soil samples is naturally occurring.

4.0 Results of the Geochemical Evaluation for Multiple Elements in Sediment

This section presents the results of the geochemical evaluation of barium, potassium, and selenium in sediment samples from Parcel 82(7). Correlation plots are provided in Attachment 1.

Barium

As discussed in Section 2.1, divalent metals such as barium tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. If a sediment sample contains a high proportion of clay minerals, then it is expected to contain high concentrations of aluminum and associated trace elements. The site and background samples form a collinear trend in a plot of barium versus aluminum (Figure 14). The site samples with the highest barium concentrations also contain high aluminum concentrations, and lie on the trend established by the other samples. These observations indicate that barium in the site samples is associated with clays at a relatively constant ratio, and is natural.

Conclusion

Barium detected in the site sediment samples is naturally occurring.

Potassium

Potassium is a major element that is a common constituent of minerals such as clays, which also contain aluminum. The background samples form a generally linear trend with a positive slope in a plot of potassium versus aluminum (Figure 15). The site sample with the highest potassium concentration also has the highest aluminum concentration, and lies on the background trend along with the other site samples. This indicates that potassium in the site samples is associated with clays and other aluminum-bearing minerals at a relatively constant ratio, and that the potassium is natural.

Conclusion

Potassium detected in the site sediment samples is naturally occurring.

Selenium

As explained in Section 2.1, selenium has a strong affinity to adsorb on iron oxides in oxic soils and sediments, so a positive correlation between selenium and iron is expected for uncontaminated samples under these conditions. Comparison to background is hindered because of the high percentage of nondetects in the background data set. However, the site sediment samples form a linear trend with a positive slope in a plot of selenium versus iron ($R^2 = 1$), and two of the background samples with detectable selenium lie on this trend (Figure 16). Selenium in the site samples is associated with iron oxides at a nearly constant ratio, and is natural.

Conclusion

Selenium detected in the site sediment samples is naturally occurring.

5.0 Results of the Geochemical Evaluation for Multiple Elements in Surface Water

This section presents the results of the geochemical evaluation of aluminum, arsenic, and potassium in the five unfiltered surface water samples from Parcel 82(7). Correlation plots are provided in Attachment 1.

Field-measured pH readings for the site surface water samples range from 6.1 to 7.44 standard units, with a mean of 6.86. These values indicate neutral conditions in site surface water. Field-measured DO readings range from 8.04 to 9.65 mg/L, with a mean of 8.80 mg/L. These readings suggest oxidizing conditions at sample locations (ORP readings are not available). Turbidity measurements range from 24.5 to 298 nephelometric turbidity units (NTU), with a mean of 167 NTU. These values indicate that most of the site samples contained a significant mass of suspended particulates. It should be noted that field readings are not available for the background samples.

Aluminum

The detected concentrations of aluminum in the site samples range from 0.349 to 6.34 mg/L. As discussed previously, aluminum concentrations in excess of approximately 1 mg/L in neutral-pH waters indicate the presence of suspended clays. Aluminum will be present in solution at a pH below about 4.0, but the Parcel 82(7) pH readings are higher than this and are in the neutral range. Thus, the detectable aluminum in the site samples is primarily associated with suspended particulates. The elevated turbidity readings support this contention (see the description of field readings, provided above).

Iron concentrations in excess of approximately 1 mg/L in neutral-pH, moderate to oxidizing conditions indicate the presence of suspended iron oxides. A plot of aluminum versus iron

permits a qualitative assessment of the amount of suspended particulates in the surface water samples (Figure 17). A strong linear trend with a positive slope is typically observed when the aluminum and iron are both present in particulate form. Just such a trend is observed here for the site and background samples. The site samples with the highest aluminum concentrations exhibit proportionally higher iron, and lie on the linear trend formed by the other samples. This indicates that the elevated aluminum is due to the presence of suspended particulates such as clays, and is natural.

Conclusion

Aluminum detected in the site surface water samples is naturally occurring.

Arsenic

Arsenic was detected in one of the five site surface water samples. As discussed previously, under natural conditions arsenic is present in waters primarily as oxyanions and its concentrations are often controlled by adsorption on iron oxides. A plot of detected arsenic concentrations versus detected iron concentrations is provided in Figure 18. The site sample and most of the background samples form a common linear trend with a positive slope. Site sample FX2002 contains only a moderate amount of arsenic relative to the background samples (0.0036 J mg/L, which is slightly below the mean value of 0.0038 mg/L for the background detections) as well as a proportional amount of iron, and lies near the center of the linear background trend. This indicates that the arsenic in the site sample is associated with suspended iron oxides at a ratio consistent with those of the background samples, and is natural.

Conclusion

Arsenic detected in the site surface water samples is naturally occurring.

Potassium

Potassium is a major dissolved constituent of natural waters, and it can also be associated with suspended clays. A plot of potassium versus aluminum is provided in Figure 19. Most of the background samples form a generally linear trend with a positive slope, indicating that some proportion of the potassium in these samples is associated with clay minerals at a relatively constant ratio. Most of the site samples lie on this trend. The sample with the highest potassium (FX2006; 4.39 J mg/L), however, contains only moderate aluminum and lies slightly above the trend established by the other samples. It is likely that the potassium in this sample is in solution. This concentration is below the background maximum of 7.12 mg/L, suggesting that it is natural.

Conclusion

Potassium detected in the site surface water samples is naturally occurring.

6.0 Summary

This section summarizes the results of the geochemical evaluations of selected elements in soil and surface water samples from Parcel 82(7).

Soil. Geochemical evaluation indicates that all of the barium, calcium, cobalt, copper, iron, magnesium, mercury, nickel, potassium, selenium, silver, and zinc concentrations detected in the Parcel 82(7) surface and subsurface soil samples are naturally occurring. The beryllium concentration in surface soil sample FX0025 (location FTA-82-DEP05) is anomalously high relative to the major element concentrations and may contain a component of contamination. All of the beryllium concentrations detected in the subsurface soil samples are naturally occurring.

Sediment. Geochemical evaluation indicates that the detected concentrations of barium, potassium, and selenium in the Parcel 82(7) sediment samples are naturally occurring.

Surface Water. Geochemical evaluation indicates that detected concentrations of aluminum, arsenic, and potassium in the Parcel 82(7) surface water samples are naturally occurring.

7.0 References

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ATTACHMENT 1

